HALIFAX
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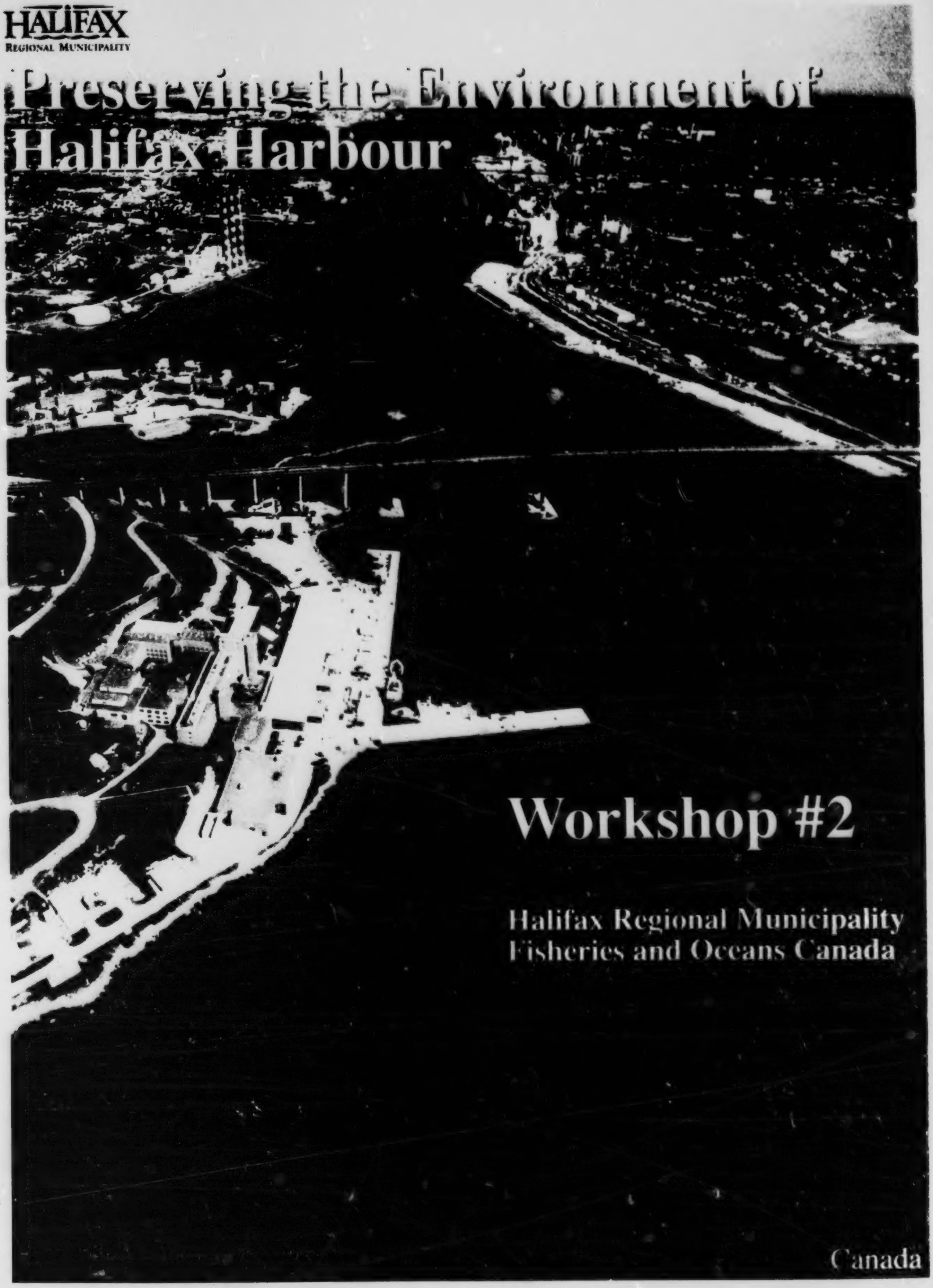
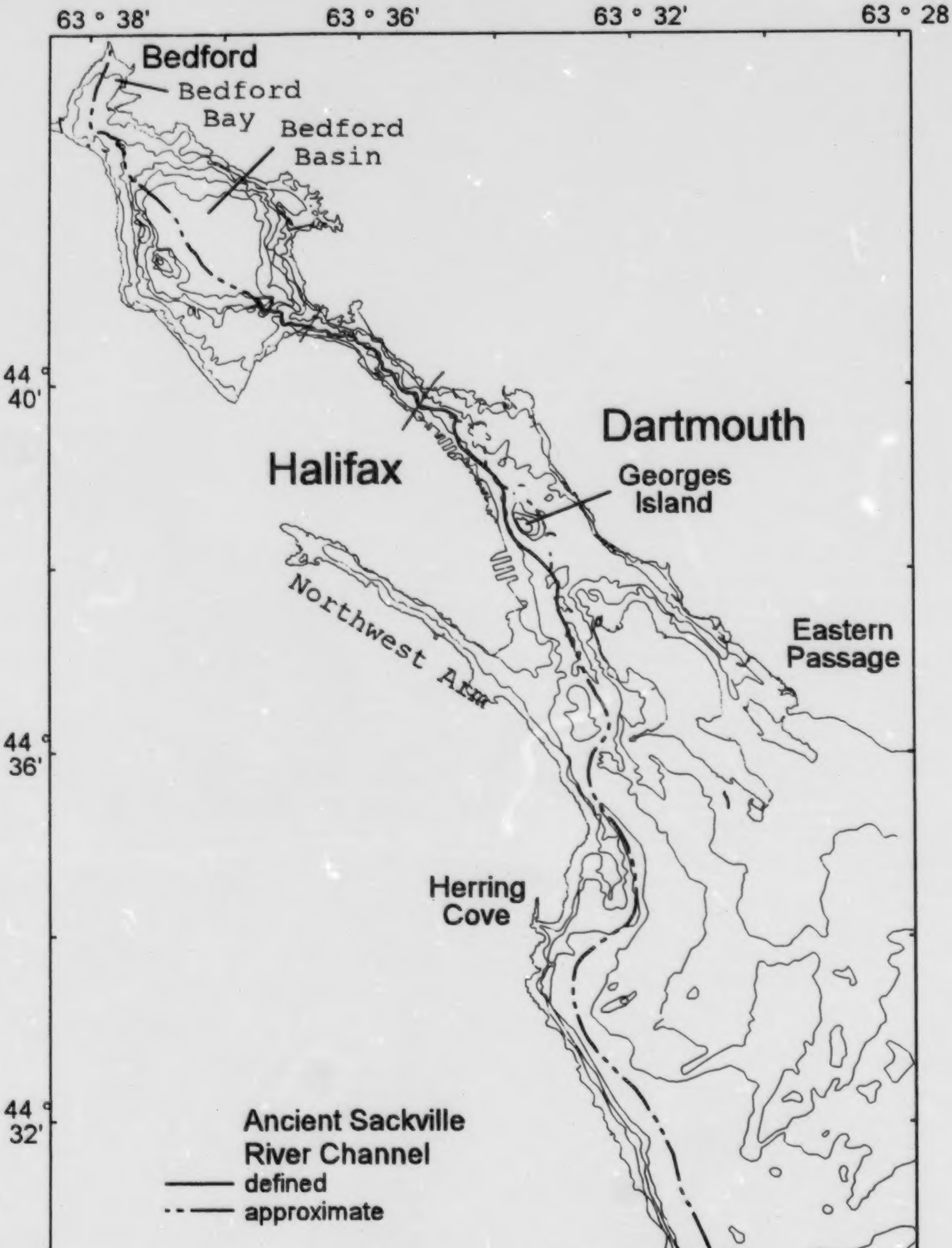
Preserving the Environment of Halifax Harbour



Workshop #2

Halifax Regional Municipality
Fisheries and Oceans Canada

Canada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Bedford
Bedford Bay
Bedford Basin
Dartmouth
Halifax
Georges Island
Northwest Arm
Eastern Passage
Herring Cove
Chebucto Head
Ancient Sackville River Channel
defined
approximate

Workshop Sponsors

This workshop is the sequel to a similar workshop carried out on March 14th-15th 2000. Like the preceding workshop, it was conceived and developed by the staff of the Habitat Management Division of Fisheries and Oceans. The Halifax Harbour Solutions Project of the Halifax Regional Municipality, co-sponsored both year 2000 and 2001, by graciously offering their support in the delivery of the agenda and committing to defray all printing costs.

Steering Committee

The Steering Committee was composed of Brian Thompson, Division Manager, Habitat Management Division, DFO; Jim Ross, Unit Head Habitat Management Division, DFO; Andre Ducharme and Gary Turner, Consultants and former employees of DFO; Brian Nicholls, Chair, Consultant and former employee of DFO and Dr Tony Blouin, Assistant Director, Halifax Harbour Solutions Project, Halifax Regional Municipality.

In addition, to discuss the Workshop goal and the strategy to achieve that goal, a meeting of key scientific staff from DFO, NRCan, HRM and their consultants was organized. The meeting took place on January 26th, 2001 and those present were:

Brian Nicholls, Chair, DFO retired (Telecom, Edmonton, Alberta)
Barry Hargreave, DFO, Scientist
Paul Boudreau, DFO, Scientist
Tony Blouin, HRM, Assistant Director, Halifax Harbour Solutions Project
Gordon Fader, DFO, Scientist
Brian Petrie, DFO, Scientist
Phil Yeats, DFO, Scientist
Ken Mann, DFO, Scientist
Gary Turner, Co-Editor, DFO, retired
Andre Ducharme, Co-Editor, DFO, retired

Preserving the Environment of Halifax Harbour

Workshop #2

Co-edited by

Andre Ducharme and Gary Turner

A gathering of stake-holders from 3 levels of government, Academia, industry, and public interest groups to: review the state of environmental knowledge in Halifax Harbour, identify information gaps in the light of future large developments and identify required actions for the preservation and restoration of fish and wildlife habitats and aesthetic values in Halifax Harbour.

Held at the Main Auditorium, Bedford Institute of Oceanograghy, 1 Challenger Drive,
Dartmouth, Nova Scotia, Canada

March 14th – 15th 2001

Sponsors: Department of Fisheries and Oceans and Halifax Regional Municipality (The Harbour Solutions Project)

The "Preserving the Environment of Halifax Harbour Workshop # 2", is a registered book of proceedings. Suggested citation format for articles within this book follows:

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Opening Welcome and Introduction to the Workshop

Welcoming Address

Jacob Verhoef

On behalf of the Federal Departments of Fisheries and Oceans and Natural Resources, it is my pleasure and privilege to welcome you to the Bedford Institute of Oceanography (BIO). Over the next two days you will be attending the Workshop on Preserving the Environment of Halifax Harbour. A quick look at the agenda for the Workshop shows at once that you have a busy and full schedule. In addition to that, I am very impressed to see the range and scope of the presentations. They range from a review of where we are, to a presentation on contaminants in both the water column and its surroundings. There are presentations on: the fauna of Halifax Harbour; a review of major development projects now, in the past and in the future, one on problems in other regions and finally presentations on community perspectives on the Harbour. This is a very comprehensive program and I am glad to see its broad scope, since it is my belief that many of the issues that we are dealing with nowadays are very complex, and we need to look at them from all perspectives prior to making any of the key decisions that set future directions.

I am also very pleased that this second workshop is being held at the Bedford Institute of Oceanography. This Federal Research Center houses a significant amount of knowledge and information, as is evidenced by the number of Workshop presenters that are now working at BIO or have worked here in the past. It is very gratifying to see that information and knowledge is being utilized as part of such an important workshop as the present one. It is my sincere hope that you will have a very successful workshop over the next few days. Once again, we are glad to host the Workshop and are looking forward to the presentations, and to a significant step forward in the discussions on the future of Halifax Harbour.

DFO's Aspirations for Fish Habitat in Halifax Harbour: Realities and Opportunities

J.B. Ross

Halifax Harbour once supported a vibrant fishery. In his first report to the authorities in London, Cornwallis reported that "the harbour itself is full of fish of all kinds...." (Ducharme, 2000). Two hundred and fifty-two years later, the harbour still supports numerous commercial and recreational fisheries and a diversity of related habitats (Rozee, 2000).

Today, the harbour is desperately trying to be all things to all people by being an industrial harbour, providing recreational and tourism opportunities, allowing for commercial and recreational fisheries, and providing areas of natural beauty. For this reason, DFO cannot apply the *Fisheries Act* and the *Policy for the Management of Fish Habitat* (the Policy) (DFO, 1986) in exactly the same way in the industrial areas of the harbour, as we would in the more pristine areas.

Policy Objectives andGoals

The Habitat Management Division of DFO is responsible for administering the habitat provisions of the *Fisheries Act*[1]. In particular, we direct a significant level of effort to section 35 which prohibits the harmful alteration, disruption or destruction of fish habitat unless authorized by the Minister. Under the Act, fish and fish habitat are defined very broadly.

> Fish are defined as: "...*parts of fish, shellfish, crustaceans, marine animals and any parts of shellfish, crustaceans or marine animals, and the eggs, sperm, spawn, larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine animals.*" (*Fisheries Act* sec. 2)
>
> Fish habitat is defined as: "...*spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes.*" (*Fisheries Act* sec. 34(1))

The *Policy for the Management of Fish Habitat* describes how we should implement the habitat provisions of the *Fisheries Act*. Specifically, it is a statement of DFO's objectives, goals, and strategies for the management of fish habitats in support of Canada's freshwater and marine fisheries. The Policy objective of a net gain of habitat is supported by the three goals of habitat conservation, restoration, and development. Habitat conservation is guided by *the no net loss* principle. The goals of habitat restoration and development are intended to complement the conservation goal by providing opportunities for a net gain of habitat.

Applying the Goals in Halifax Harbour

The conservation goal is the standard that must be met by all development proposals that could have an impact on freshwater or marine resources in the harbour. Unless authorized by the Minister, projects must not result in a harmful alteration, disruption or destruction of fish habitat.

The project design phase is where efforts should be first directed to ensure the impacts to fish habitat are minimized. This can be accomplished through proper project design, or if required, project relocation to conserve valued habitats.

It is not always feasible to completely eliminate impacts at the design stage. In these instances, mitigation measures must be considered that will conserve fish habitats. Options available to do this include defining construction windows, use of appropriate construction methods, ensuring fish passage around obstacles during and after construction, etc.

If residual impacts remain, an authorization under section 35(2) of the *Fisheries Act* may be considered. This authorization will require that the proponent provide compensation for any lost habitat, in addition to the preventative measures of project redesign and mitigation. Compensation is usually in the form of restoration or development of similar habitat in sufficient quantity and quality to ensure there will be no net loss of habitat in the area.

Fisheries Act authorizations also trigger *the Canadian Environmental Assessment Act* (CEAA) legislation. The proponent would be required to collect and provide sufficient information under the CEAA legislation to permit an assessment of the significance of the impacts of the project[2].

As mentioned previously, it may not be possible to apply the Policy in the same manner in the industrial areas of the harbour as we might in the more pristine areas. But, within similar areas of the harbour, it should be applied consistently. This means, for instance, we could be looking at infills differently in the industrial areas of the harbour than we might in the Northwest Arm or Bedford Basin. Residents on the Arm or Basin may have to scale back their plans for an infill or wharf that could increase the value of their property, but remove valued habitat from the public domain. This is in part because the industrial sections of the harbour, although they do provide fish habitat, are now composed largely of habitat that would support the migration of fish and provide food supply, whereas in the Arm and the Basin there is a greater diversity of habitats.

If conservation can be considered as maintaining the status quo of fish habitat, then the two remaining goals of habitat restoration and development may be seen as contributing to the overall quantity and quality of fish habitat. The question here is, "are there restoration and development opportunities in Halifax Harbour?" If we look to other examples, such as Hamilton Harbour, which will be discussed by Victor Cairn in this workshop, and the lessons of Chesapeake Bay, then the answer is "yes". Bob Rutherford will be elaborating on restoration opportunities in the context of Halifax Harbour.

Responsibilities of Stakeholders

As with every publicly owned resource, we all bear some responsibility for it. This is no different with regard to the protection of fish habitat. Government regulators, scientists (both within government and academia), developers, resource users, environmental non-governmental organizations (ENGO), and the public at large all have roles to play. In addition, regulators must work with all stakeholders to help them develop a vision of the harbour and help them achieve it.

Government regulators must ensure that the legislation designed to protect habitat is respected and that the goals encompassed by *no net loss* are achieved. Regulators must cooperate with proponents and other resource users to advise them of their responsibilities as early as possible in the project planning process.

Scientists must provide the tools that habitat managers need to properly assess the impacts of proposed projects. In the harbour, tools, such as habitat classification maps that identify habitat-related constraints are required.

Some important questions that require answers are:

- When should we consider that a harmful alteration, disruption or destruction of habitat may occur as the result of a project?
- What proxies can be used to make these determinations? These must be scientifically valid, cost-effective, and easy-to-use.
- When is mitigation required and what effective compensation options exist in the harbour?
- What are the effects of shoreline changes, and pollution in both the sediments and the water column, on fish habitats and the fisheries in the harbour?
- How should we measure the significance of cumulative effects?

In general, there is a great deal of research and data on the environment of Halifax Harbour. It resides in numerous places and, as a result, access to it is a problem for developers, resource managers, planners, and the public. Making it available in one large database would greatly enhance environmental decision-making and provide greater transparency to the environmental assessment process[3].

Developers and other project proponents must ensure that they enter into discussions with DFO early in project planning. They must include appropriate consideration of habitat values in their projects. Redesign or relocation[4] to address habitat concerns can be costly in the later planning stages.

ENGOs and the public in general must make their visions and hopes for the harbour known to decision-makers. It is important that this be done in meaningful and helpful ways in consideration for the limitations of the legislation.

DFO's Aspirations

Each stakeholder has many overlapping concerns and responsibilities with regard to the protection of natural resources such as fish habitat. Some of these can be addressed through integrated management planning. This is a planning tool that uses an ecosystem approach to help develop a shared vision of the future, and has environmentally sustainable development as a goal. Bob Rutherford will speak in part on this later in the workshop.

The drafters of the *Fisheries Act* were clever enough to realize the complexity of habitats and the connections between the various species that inhabit them. They appreciated the importance of maintaining biodiversity. Perhaps, most importantly, they understood that it is a false and dangerous notion that all we need to do is protect a small patch of habitat and we can have our way with the rest.

DFO will continue to apply the *Fisheries Act* and the *Policy for the Management of Fish Habitat* to help conserve, restore, and develop fish habitat in the harbour. It is important to understand that DFO will not willingly relinquish critical habitat, nor will we accept a net loss of habitat in Halifax Harbour. Our wish is to work with industry and other stakeholders to ensure that habitat values in the harbour receive the priority they deserve in the planning process.

As we begin to address the issues of this workshop, I would like us to remember that Cornwallis held great hopes for the harbour as a place for "... fish of all kinds ..." and that it is up to all of us, working together, to preserve the environment of Halifax Harbour

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[1] For a more complete discussion on the Fisheries Act see: Thompson, B.T. 2000. Halifax Harbour-Fisheries Act Implications. Proceedings of Workshop #1, Preserving the Environment of Halifax Harbour. Halifax, NS. Mar. 14-15, 2000. p77-83.

[2] For a more complete discussion on CEAA see: Coulter, B. 2000. The Canadian Environmental Assessment Act. Proceedings of Workshop #1, Preserving the Environment of Halifax Harbour. Halifax, NS. Mar. 14-15, 2000. p103-105.

[3] For a more complete discussion of options for habitat conservation and protection see: Habitat Conservation and Protection Guidelines. Fisheries and Oceans, Ottawa. 1998, second ed. [www.dfo-mpo.gc.ca/communic/comm1_e.htm]

[4] Numerous examples of such projects exist. For one example see: Stewart, J.E., Penning-Rowsell, E., and Thornton, S. 1993. The LENKA project and coastal zone management in Norway. OECD Documents, Coastal Zone Management: selected case studies. p257-281.

References

DFO. 1986. Policy for the Management of Fish Habitat. Fisheries and Oceans, Ottawa. 1986.

Ducharme, A. 2000. Halifax Harbour-Fisheries Act Implications. Proceedings of Workshop #1, Preserving the Environment of Halifax Harbour. Halifax, NS. Mar. 14-15, 2000. p2-3.

Rozee, P. 2000. Halifax Harbour-Fisheries Act Implications. Proceedings of Workshop #1, Preserving the Environment of Halifax Harbour. Halifax, NS. Mar. 14-15, 2000. p164-165.

Objectives of Workshop #2

Brian Nicholls, Chair

The presentation by Jim Ross of DFO's Habitat Management Division sets the scene for this workshop. As we deliberate on the preservation of the environment of Halifax Harbour over the next two days, please bear in mind DFO's aspirations and objectives for the management of the harbour's environment as outlined by Jim.

This workshop has been organized by Andre Ducharme on behalf of the Federal Department of Fisheries and Oceans (DFO) and the Halifax Regional Municipality (HRM). Andre, who is retired from DFO (Head of Habitat Management), invited me, another retiree, to chair the event. I worked at BIO for many years, my last position being Head of Environmental Assessment in the Marine Environmental Sciences Division. I was involved in Halifax Harbour environmental issues in the late-1980s and throughout the 90s, serving, for example, as a member of the Halifax Harbour Task Force.

In my remarks this morning I shall review the objectives of the workshop, but before I do this, I want to provide you with some background information.

You will note that the title of the workshop is "Preserving the Environment of Halifax Harbour." By way of clarification:

- - **preserving** is used here in a broad sense, and is intended to include the protection, conservation, restoration and enhancement of the harbour

--**environment** encompasses the marine environment, which provides the habitat[1] for the fish of the harbour; but in addition to the marine environment we shall also be addressing the other environments of the harbour, i.e. adjoining freshwater systems, the land around the harbour that provides important habitat for wildlife other than fish, and also the atmospheric environment.

- - **Halifax Harbour** includes Bedford Basin, the Narrows, the Inner Harbour, the Middle Harbour, the Outer Harbour, and the Harbour Approaches (extending out to approximately the line between Devil's Island and Chebucto Head).

As you are probably aware, this is the second workshop in the series. Some, but not all of you, were at the first workshop, which was held at the same time last year. The 2000 workshop followed consultations between staff of the Federal Department of Fisheries and Oceans (DFO) and the Halifax Regional Municipality (HRM), as a result of which it was decided that the time was right to hold discussions with other interested parties on the launching of an initiative on the preservation of the environment of Halifax Harbour. The discussions recommended by DFO and HRM took place through the mechanism of workshop #1.

In summary, Workshop #1 consisted of sessions in which papers were presented on:

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[1] The Fisheries Act defines fish habitat as "Spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes."

(a) the ecological description of the harbour;

(b) the anthropogenic stresses on the harbour;

(c) the federal and provincial regulations applicable to the harbour; and

(d) the interests of non-regulatory stakeholders.

This was followed by "looking to the future" discussions (in small groups) on preserving the environment of the harbour, which led to the identification of key issues and suggested actions.

The interest and enthusiasm of the workshop participants was such that DFO and HRM decided to proceed towards the launching of an initiative on the restoration and preservation of the environment of the harbour. Hence this second workshop. This workshop comprises five sessions (parts) that form a logical progression leading to the development of recommendations in support of the preservation of the environment of the harbour:

(1) The state of environmental knowledge;

(2) Spectrum of harbour activities;

(3) Measurable impacts on fish habitat;

(*followed by summation of available knowledge*)

(4) Achievable goals;

(5) Development of recommendations (see below).

The objectives of this workshop are to:

(A) Review available knowledge on the harbour (Parts 1 to 3);

(B) consider possible achievable goals on the preservation of the harbour's environment (Part 4);

(C) Develop a vision statement (or statements) applicable to the preservation of the environment of Halifax Harbour that encompasses the views of all of the groups represented at this workshop (Part 5); and

(D) Develop recommendations (to DFO, HRM, other government agencies, industry and the public) aimed at addressing:

- knowledge gaps;
- abating or containing contamination sources;
- preserving existing habitats;
- enhancing aesthetic and other values of the harbour; and
- other related issues (Part 5).

It should be noted that the envisaged Halifax Harbour program would be a cooperative initiative, involving a variety of government agencies, NGOs, stakeholders and other interests; also that it would be complementary to the Harbour Solutions Project.

Now, a few words on the logistics of this workshop:

(1) If you don't have a copy of the proceedings of Workshop #1, and would like one, please see Debbie Campbell at the registration desk.

(2) Given the very full program it is important that all speakers remain on schedule. Note that anything important left out because of insufficient time can be provided to DFO (refer to #5, below), either during the meeting or within a few days of the conclusion of the workshop, for inclusion in the proceedings of the workshop.

(3) The contact person for audio-visual requirements is Brooke Cook.

(4) The poster papers are an integral part of the workshop, and it is important that

participants take time to review these.

(5) Proceedings of the workshop will be issued. Priority will be placed on producing these as soon as possible (the target date is May, 2001). You will all receive a copy. Gary Turner is the contact person for the proceedings.

(6) Coffee-breaks and lunches will be provided throughout the two days.

(7) Participants are encouraged to remain to the end of the event. There will be a draw for a piece of Nova Scotia Crystal at the conclusion of the workshop--you have to be present at that time to be eligible to win it!

In closing, I wish everyone a successful workshop!

Part 1

The State of Environmental Knowledge

Highlights of Previous Workshops

Don Lawrence

Physics

- Lawrence (89tr): physical oceanography and modelling as related to sewage disposal was reviewed. Some general principles were illustrated by reference to the 1985-1987 study.
- Petrie (89w): the inlet was classified as 'partially mixed'. Layered flow was predicted and observed, varying in strength with seasonal stratification.
- Tee & Petrie (91w): a 2-dimensional model was used to examine the relative importance of three forcing factors on the circulation and salinity in the Harbour. Data from the winter of 1970 was used. Sackville River runoff was the major contributor to the 2-layer estuarine flow. Wind could enhance this flow and sewage outflow could reduce it.
- Lawrence & MacNeil (89w, 91w): the outer harbour field program and modelling study were finished. Intermittent layered flow was observed. The normal and reversal fluxes occurred on time scales of about 8 days and were correlated with meteorological events. Flux strengths were typically comparable to the tides and double the mean flow, but extreme values of up to five times tidal were observed. A numerical model was developed to represent the coherent part of the current field over 23 days, with time dependent upper- and lower- layer currents and layer thickness. The observation period was judged typical of summer conditions.
- Rapporteur's identification of needs:
  - A) 1989 (Wells): finish mapping the seafloor. Understand distributions of effluents under various flow regimes.
  - B) 1991 (Gordon): will the intrusions over the Narrows Sill into Bedford Basin be affected by the outfall consolidation? Where will particulates from a single outfall ultimately be deposited? Ensure models deal effectively with sediment transport, deposition and resuspension.

Water Quality

- Dalziel et al (89tr), Yeats & Cranston (89w), Yeats (91w), Dalziel et al (91tr): a comprehensive yearlong study was completed. Six sites were occupied on five occasions during 1989 for eight particulate and seven dissolved metals, nutrients, reactive Hg and suspended solids. Five sites were near contaminated zones; one was in the clean outer waters. The distribution patterns were similar on all cruises:
  - Particulate metals: for Cu, Pb and Zn, levels were significantly elevated compared to offshore, though similar to other nearshore/estuarine regions, whereas Cd and Ni were only slightly elevated. Mn and Zn were seasonally variable in the deep waters of Bedford Basin and inversely related to dissolved oxygen, suggesting seasonal flushing and a flux from bottom sediments related to redox cycles. Pore water measurement methods need to be developed in order to quantify the flux.
  - Dissolved metals: levels were only slightly elevated – 80% of values for Cd, Cu, Ni and Pb were within 2x of Shelf values, and Fe, Mn and Zn were within 4x. The spatial variability of Pb and Zn was attributed to anthropogenic sources. The uniformity of Cd and Cu

was related to river runoff. Cu, Mn and Ni varied linearly with surface salinity, indicating freshwater source control.
  - Nutrients: phosphate levels were high in all samples, indicating sewage contamination. All nutrients had high levels in the deep waters of Bedford Basin when oxygen levels were low.
  - Reactive Hg: no overall trends were noted. The mean levels were similar to those on the Shelf.

- Hargrave & MacKnight (89w): a method is being evaluated to measure fluxes of dissolved trace metals to and from the bottom sediments, at two sites of contrasting concentrations.
- Isenor & Hurlbut (91w): the numerical model (Lawrence & MacNeil) was used to predict the concentrations of coliform bacteria and suspended solids around 5 hypothetical sewage outfall sites in the Outer Harbour. During the simulated period, two large non-tidal events occurred. Thus the episodic nature of water quality problems could be investigated. The results indicated that a properly designed outfall could be successfully sited anywhere in the deeper regions of the study area.
- Rapporteur's identification of needs:
  - A) 1989: improve the resolution of the model. Acquire more data from the outer harbour.
  - B) 1991: determine the assimilative capacity of Bedford Basin for various anthropogenic wastes.

Sediments

(a) Geology

- Fader & Miller (89w, 91w): comprehensive acoustic surveys were carried out during 1989 and 1990, supplemented with sediment sample collection and bottom observations with ROVs. A series of 22 maps was produced. Sediment transport indicators suggest net transport northward. The area of gas charged sediment appears to have decreased by 20% over 15 years. The thickest mud deposits were north of McNabs and Georges Is. Many anthropogenic features were identified in the Inner Harbour and Bedford Basin.
- Fader (00w): synthesis of the data from all the modern survey techniques has led to a new interpretation of the geological history of the Harbour. Very high resolution patterns of sediment transport and deposition have been produced.
- Syvitski & Asprey (91w): an underwater photographic package was developed capable of gathering, for the first time, in-situ information on individual marine suspended particles down to 35 microns and undisturbed flocs. Data were analysed from three sites in the Harbour and Basin, principally in 1989 and 1990 and during four climate seasons. The conclusions:
  - Concentrations of SPM were high throughout the inlet when river runoff was high, but the proportion of flocs was reduced.
  - Settling velocities had means 60-170m/day, highest in spring and autumn when inorganic matter was highest.
  - As size of flocs increases, they become more elongated, the particle density decreases towards neutrally buoyant, and settling velocities increase. Sizes are largest in summer.

(b) Geochemistry

- Buckley & Hargrave (89tr): surface sediment samples collected in 1986 and 1988 from 224 sites throughout Halifax Harbour were analysed. Levels of trace metal and organic contaminants were 2 to 6 times higher than on the Scotian Shelf, in areas around sewage outfalls and near some industries. Dispersion patterns indicated inward movement. More analyses and experiments are needed to determine mobility into the water column.

- Buckley (89w): anomalous concentration profiles of metals and organic contaminants were observed adjacent to sewage outfalls. Below 10-20 cm, suboxic reduction and precipitation of metals may occur.
- Winters & Buckley (91w), Buckley & Winters (91w): the stability of metal contaminants in the Harbour was investigated. Observed concentration patterns closely matched organic matter patterns. The implication is that if sewage treatment reduces organic matter deposition, then existing organics may be more readily oxidized and this could result in metals being freed up to re-enter the overlying water column. Laboratory tests on Harbour mud samples confirmed that significant proportions of Pb, Zn and Cu could be leached out by acidic oxidizing or reducing reagents. This demonstrated that the present metal immobility could be upset by future water quality management strategies unless care was taken.
- Smith (89w), Smith et al (91w): Pb210 and Cs137 dating can show the history of metal inputs to the sediments over the last 100 years. Sediment cores from various parts of the Harbour were examined. The highest sedimentation rates (~ 1cm/yr) were found near Georges I. and some regions of Bedford Basin, and lesser rates in the Northwest Arm. Metal contaminant levels rose from 1880 to 1970, reaching peak values comparable to the maxima reported for any urban coastal marine region. The decline since 1970, especially in Pb, is perhaps due to decreased usage of Pb-based marine paints. In the Northwest Arm, one core showed increasing levels of aliphatic contaminants since 1880, a characteristic of sewage. Levels of aromatic hydrocarbon combustion products peaked in 1950, subsurface, then declined slightly, possibly due to decreasing usage of coal and wood fuels.
- Gardiner & Buckley (91w): levels of total Hg in the Harbour sediments rose from ~1900 to 1970. Exceptionally high values were found near Queen's Wharf. Potential sources are paints, medical and dental uses and fungicides.
- Cranston (91w): methane, the result of bacterial degradation of organic carbon-rich sediment, has been found in many regions of the Harbour at 1-15m below the seabed. Quantitative measurements are not yet possible.
- Rapporteur's identification of needs:
    - A) 1989: describe movement of suspended sediments. Study properties of metals in sediments. Study sources and profiles of lead. Measure trace metals in sediment pore waters. Study influence of oxidized water on metal leaching from sediments.
    - (B) 1991: determine the implications of the methane in the sediments and its origin. Devise a long-term strategy to manage the potential remobilization of trace metals. Determine the true extent of organic contaminants and their relative danger.

Biology

(a) Microbes

- Pett (89w): concentrations of bacteria are 3 to 10 times higher in the Harbour than offshore, indicating a higher utilization of dissolved organic carbon.
- Bridges (91w): a Harbour sediment sample was transferred to a laboratory water column as part of an undergraduate student experiment. Over several months, new

equilibrium concentrations of the metals in the water were noted, attributed to temperature induced changes in the microbiological activity in the sediment.

- Rapporteur's identification of needs:
    - A) 1989: determine the use of dissolved organic carbon by microbes.

(b) Plankton

- Slauenwhite (89w): peaks in the concentrations of two species of dissolved Cu coinciding with a spring plankton bloom were found to be related to the spring Sackville River runoff peak, and not to biological activity.

(c) Macrobenthos

(i) Lobster

- DFO Microbiology Lab (89tr): samples were collected from Herring Cove, Halifax and Sambro Harbours over May to June 1988, and analysed for bacteriological contamination. No Salmonella was present. Coliform levels were below human health levels for all properly cooked samples.
- Uthe et al (89tr), Prouse (89w), Prouse (91w): the resident population was sampled at 3 areas in January 1989. Levels of heavy metals in digestive gland and cooked meat were below human health risk levels, especially for Cd. Levels of PAHs and PCBs in digestive gland were generally below human health risk levels. Sampling was repeated in the autumn at the 3 contaminated sites and at two Outer Harbour control sites. Again, concentrations of heavy metals and PCBs and PAHs in cooked samples were below health risk levels.
- Rapporteur's identification of needs:
    - A) 1989: determine the significance of lobster contamination.

(ii) Mussels

- Ward (89w): metal concentrations showed some increase near sewage outfalls.

(iii) Polychaetes

- Peer (89w): the low diversity, especially in Bedford Basin, suggested stress, possibly due to pollution and anoxic events.
- Rapporteur's identification of needs:
    - A) 1989: determine the cause of die-off at selected sites.

(iv) General

- Hargrave et al (89tr): grab samples were taken in Bedford Basin at 7 sites, January to May 1970, 4 photographic transects were done near Tribune Head, October and November, 1987, and photos were taken of bottom grabs throughout the Harbour in August, 1988. Extensive beds of common species of macrophytes were found on all the rocky bottom nearshore at Tribune Head. Macrofauna species diversity was very low in central Bedford Basin, highest near the Mill Cove sewage outfall. Biomass was also highest off Mill Cove. These Mill Cove values were comparable with other coastal embayments.
- Tay et al (91w): a series of bioassay tests were carried out on Harbour sediments contaminated by heavy metals and organics. Biological effects were noted on two of the four species tested, closely associated with high PAH levels. Reduced benthic faunal diversity corroborated these results. Also, fish lesions suggested chronic effects were detectable. Baseline data needs to be collected.
- Hargrave et al (91w): a complete set of physical, chemical and biological variables was measured for six sediment stations along the length of the Harbour during the summer of 1990. Correlations were then sought against two types of sediment

toxicity bioassays. Significantly correlated were organic carbon, PCBs, PAHs and trace metals, and uncorrelated were fauna biomass and diversity.

- Vandermeulen & Mossman (91w): a four year study in Sydney harbour/estuary demonstrated that the EROD enzyme system of local winter flounder was highly sensitive to PAH levels in the bottom sediments. It was proposed to apply the same method to Halifax Harbour to evaluate local contaminant bioavailability and sediment quality.
- Rapporteur's identification of needs:
  - a) 1989: is benthos abundance related to metal leaching, physical disturbances, or episodic physical-chemical events? Conduct biological effects monitoring using up-to-date techniques.

(d) Fish

- Ducharme (89w), Ducharme (91w): there is a valuable catch of lobster and finfish in the Harbour. For lobsters, northward from McNabs I. only 2-3 fishermen work, but southward nearly 60 work. Finfish effort increases southward and is very seasonal.
- Rapporteur's identification of needs:
  - A) 1989: continue to document details of the fisheries.

(e) Mammals

- Brodie (00w): seals and whales are present in the Harbour year round. Their abundance is quite variable as they and their prey have various migration patterns.

(f) General

- Rapporteur's identification of needs:
  - A) 1991: what are biological effects of periodic flushing events? What are biological effects of sediment-bound contaminants? Make use of the existing contaminant gradients to develop new methods for environmental assessment. The Inlet is a resilient ecosystem that is already responding positively to actions taken to minimize contamination.

Management

(a) Water Quality Monitoring

- Hurlbut (89w): a modelling system for coliform bacteria and dissolved oxygen has been developed. Its utility in explaining present concentrations and predicting the impact of any sewage treatment options is explained.
- Barchard (89w): any monitoring program must meet the needs of all the stakeholders as applied to water, sediment and environmental quality. Public and corporate inputs must be provided.
- Boyle (89w): case studies of three other harbour/estuary areas were examined with respect to their processes for identifying harbour-use goals. The results were used to develop an Inter-Municipal Planning Strategy for Halifax Inlet.
- Rapporteur's identification of needs:
  - A): what hypotheses should be addressed by the sewage treatment monitoring plan?

(b) Sewage Treatment

- Cote (89w): a summary of the status of the Fournier Task Force was given. The uses and water quality objectives for the Inlet had not been finalized.

(c) General

- Hargrave & Lawrence (89tr): a bibliography of the Harbour, Basin and adjacent coastal waters was compiled. Over 200 studies, charts and maps were cited, arranged by author.
- Plasse (91w): an inexpensive, user-friendly desktop GIS system 'INFOCUS' was

proposed for the Inlet to manage resources.

- Mann (00w): the functioning of the ecosystem in Halifax Harbour was described. Estuaries are normally much more productive than open coastal waters, because the fresh water driven circulation brings nutrients up towards the surface. But at present, the Harbour does not have the biological productivity and diversity that it once had. The decline can be attributed to a combination of man made problems – excess river silt, raw sewage, chemical contaminants, excess nutrients, and loss of habitat.
- Buckley (00w): the 3 environmental issues that are of concern and should be managed are aesthetics, loss of habitat and human health risks. The Harbour is poorly flushed so most contaminants stay within. The sediment contamination levels are relatively high for an urban harbour. Most of the sediment contamination comes from raw sewage, the remainder from land leaching and drainage. The reservoir of contaminants in the sediments poses a serious threat to future environmental quality, as many of the metals are potentially reactive and so could be remobilized. Sewage treatment will not immediately reduce any contamination already residing in sediments.
- Rapporteur's identification of needs:
  - A) 1989: identify all stakeholders. Identify harbour uses by season. Develop a clear set of harbour use goals. Set sewage water quality objectives. Study the harbour holistically, especially relating data of the water/sediment quality and contaminants groups.
  - B) 1991: what are the best procedures to develop and maintain a regional database? The environmental management must be holistic – sewage treatment is just one of the issues. Some future workshops might focus on particular environmental issues. Following completion of the present projects, a synthesis of the data should be undertaken, perhaps in a form suitable for the general public. Educators at all levels should make better use of the Inlet and its environmental issues.

Reference Coding

- 89w Proceedings, First Halifax Inlet Research Workshop, at BIO, 9 Nov 1989.
- 89tr Investigations of Marine Environmental Quality in Halifax Harbour. H.B.Nicholls ed., Cdn Tech Rept. of Fisheries and Aquatic Sciences, No.1693, July 1989.
- 91w Proceedings, Second Halifax Inlet Research Workshop, at BIO, 13 Feb 1989.
- 91tr The Distribution of Nutrients, Suspended Solids, Dissolved and Particulate Metals in Halifax Harbour. J.A.Dalziel, B.P.Amirault and R.T.T.Rantala, Cdn Tech Rept. of Fisheries and Aquatic Sciences, No.1826, 1991.
- 00w Preserving the Environment of Halifax Harbour. Workshop #1, Andre Ducharme ed., HRM and FOC, 14-15 Mar 2000.

Rapporteurs and Chair Summaries

1989	P.G.Wells, in 91w, page 7.
1991	D.C.Gordon Jr., in 91w, pages 36-41.
2000	H.B.Nicholls, in 00w, pages 157-162.

Historical Perspective of Metal Contamination in Halifax Harbour

Dale Buckley

Introduction

Previously published papers on the geochemical characteristics of sediments in Halifax Harbour have illustrated the distribution of contaminant metals in surficial sediments (Buckley and Winters, 1992) and in profiles of subsurface sediments (Buckley et al. 1995; Gearing et al. 1991). These reports summarized results of chemical analyses of hundreds of sediment samples taken from all parts of Halifax Harbour from the southern seaward approaches of the harbour to Bedford Bay in the northern part of the marine inlet. From these data it was possible to indicate the main sources of contamination from sewer discharges around the metropolitan area to surface drainage inputs from rivers and streams, as well as leaching of an old landfill site located in the north end of the city of Halifax. Evaluation of the profiles of contaminant metals in sediment cores collected from various sites in Halifax Harbour allowed estimation of the degree of contamination with respect to background concentrations of metals that existed before significant contamination occurred more than 150 years ago. These studies indicated that sediments in Halifax Harbour are amongst the most highly contaminated sediments known in the industrialized world. The sediment core profiles illustrated the fact that metal concentrations in sediments deposited in the latter part of the 20th century were from 3 to 100 times the concentration in sediments deposited before the founding of the city of Halifax. The greatest degree of contamination enhancement was found for the metals Pb and Hg. It was also noted from the earlier published chemical data that the form of metal associations changed from source to source and over time; indication that some forms of metal association were metastable because they were complexed with oxidizable organics or sulfides.

The Historical Perspective

In this paper concentrations of Zn, Pb, Cu, and Hg in sediments are depicted in a series of time-slice maps that illustrate the distribution of these metals over selected time intervals from 1890 to 1990 (Figures 1 to 4). The base maps for each of the time periods illustrate the changes in shoreline over time. Location of geographic features of the entire harbour is shown on the base map included in the introduction to this workshop proceedings volume. Significant changes in shoreline and harbour development begin with the wharf structures in the central Halifax waterfront before 1890, followed by expansion of shipping terminals in the southern part of Halifax, toward Pier C, in the period between 1890 and 1930. Note that the railway bridge that crossed from the northern peninsula of Halifax to Dartmouth was destroyed in the 1890s. Industrial development on both the Halifax and Dartmouth waterfronts expanded significantly during this 40- year span. Probably one of the most important developments was the establishment and expansion of the Canadian Navy Dockyards south of the area formerly known as Richmond in northern Halifax. The first bulk loading wharfs in the area northeast of Point

Pleasant Park were also developed during this time.

By 1970 there were a number of new developments in the Harbour. The Angus L. MacDonald Bridge was built in the mid 1950s, landfill operations had significantly altered the shoreline in the Seaview Point area, and construction of the first container pier in the south end of Halifax was nearing completion. These developments may have had a significant impact on the cross sectional area of the central harbour.
The final time-slice map, representing the period around 1990, shows the harbour shoreline much as it is at present. Major developments between 1970 and 1990 were construction of the McKay Bridge, and development of the second container pier for Halifax, located in Fairview Cove. This latter development extended the shoreline into Bedford Basin and covered a large area of nearshore sediment in Fairview Cove.

In each of the four figures the distribution of metals in subsurface sediments is depicted as determined from chemical analyses of subsamples from cores. In some cases there were supplemental data obtained from sampling and analyses of surficial sediments collected in 1970. The age of samples obtained from sediment cores was determined by using a ^{210} Pb and ^{137} Cs dating method (Buckley et al., 1995).

In each of the maps representing metal concentrations in sediments dated at about 1890 there are only small areas of concentrations above the background levels. In all cases these anomalous areas are adjacent to the waterfront along the waterfront of central Halifax and in Dartmouth Cove. This distribution suggests that the contamination is associated with the shipping wharfs and shipyards. The greatest anomaly at this time was the concentration of Hg (at 2.5 ppm) adjacent to the waterfront of south-central Halifax. The source of this contamination is speculated to be from the use of coal fuels used in homes, foundries and shipyards (Buckley et al. 1995)

By 1930 contamination of harbour sediments was extensive, reaching all parts of the harbour system inside (north) of Point Pleasant. The greatest concentrations were still along the waterfront of Halifax where Pb and Zn rose to more than 200 ppm, Cu greater than 60 ppm, and Hg peaked at 4 ppm. There were also anomalous concentrations of all of these metals adjacent to Seaview Point and Fairview Cove. This area had been used as the main waste and refuse disposal area for the city of Halifax, and there is clear indication that the shoreline disposal area was not containing leachates that were probably high in metal content. The expanded anomalous area of metal contamination along the north and central part of the Halifax waterfront appears to implicate the Navy Dockyards and ship repair facilities that were greatly expanded in this area after World War I. Pb was extensively used in marine paints during this time (Buckley et al. 1995) and therefore the anomalous concentrations of Pb near the Halifax and Dartmouth shipyards is to be expected. Zn was extensively used in galvanized metals, especially in marine shipping applications. This metal was also being used in marine paint.

By 1970 the most intense contamination in all areas of the harbour had occurred. The most widespread of these metal contaminants was Zn, that reached a maximum concentration of 640 ppm near the historical waterfront of Halifax. Areas of central Bedford Basin also contained sediments with concentrations of Zn between 290 ppm and

460 ppm. The central channel of the Northwest Arm also reached maximum contamination levels during this time, with concentrations reaching 270 to 350 ppm. The widespread dispersion of Zn contamination north and northwest of Seaview Point indicates that the landfill site had become a major source. By 1970 Fairview Cove had become highly contaminated with Zn and Pb. AlsoTufts Cove on the northern Dartmouth shore had become highly contaminated by 1970 and clearly indicated that this was a relatively new source of metal inputs to the harbour. This probably reflects the expansion of industrial development in the Dartmouth Industrial Park, and waste discharge from the power plant at Tufts Cove. Hg contamination along the Halifax waterfront was still severe, but was beginning to reflect a trend toward less general concentration. Two exceptions to this general trend were found adjacent to the Canadian Naval Dockyards and the south central Halifax waterfront where concentrations of Hg continued to increase. Maps of the 1970 contamination illustrate two other significant aspects: (1) contamination by all four metals was spreading southeast from the central harbour into the main western channel near Point Pleasant, and into the northern part of Eastern Passage; (2) high levels of contamination were now widespread in Bedford Basin, due in part to dumping of waste dredge materials in the Basin (Buckley et al. 1995).

By 1990 the general level of contamination represented by all four metals was less than it had been in 1970. However, sources from the consolidated sewers were now evident. The consolidated sewer at Duffus Street, north of the MacDonald Bridge on the Halifax waterfront, was clearly a major source of Hg and Cu, with somewhat less influence on Zn and Pb contamination. The major contributions of the sewer outfalls at Tufts Cove and Dartmouth Cove are evident for all metals. The consolidated outfall at Pier A became a very significant source of Hg, Pb and Zn contamination. The highest concentration of Hg found in any part of Halifax Harbour at any time was found adjacent to the outfall at Pier A (10.0 ppm). The source of this contamination is ascribed to the hospital and university institutions located in the southern part of Halifax (Buckley et al. 1995). A similar pattern of contamination is also evident around the consolidated sewer outfall located near the seaward end of the Northwest Arm.

Summary

Time-slice maps of Halifax Harbour depicting sediment concentrations of four metals demonstrate that significant contamination began along the city waterfronts of the central harbour some time before 1890. This contamination appears to be mainly associated with shipping terminals and ship repair facilities in Halifax and Dartmouth. Hg may have been derived mainly from coal fuels, but Pb was more likely derived from paints. By 1930 contamination had spread along the entire waterfront of Halifax and into Bedford Basin. The main sources of contamination appear to be the expanded industrial and navy facilities along the Halifax waterfront and from leaching of the landfill site on the northern shoreline of peninsular Halifax. In the decades before 1970, contamination of sediments reached the highest concentrations and became most widespread throughout the inner Harbour. The sources of this mid 20th century contamination are evidently a combination of industrial waste, municipal sewage discharge, and leaching of a land disposal site. Contamination had reached sediments in all parts of the inner harbour and had begun to spread toward the southern approach channels. Maps representing the latest contamination in 1990 show that the general level of contamination was less than it had been 20 years earlier. However, the increasingly significant impact of the main consolidated sewer discharges as compared with industrial and land waste disposal is evident.

References

Buckley, D. E. and Winters, G. V. (1992) Geochemical characteristics of contaminated surficial sediments in Halifax Harbour: impact of waste discharge. Canadian Journal of Earth Sciences, V. 29, no. 12 pp. 2617-2639.

Buckley, D. E., Smith, J. N., and Winters, G. V. (1995) Accumulation of contaminant metals in marine sediments of Halifax Harbour, Nova Scotia: environmental factors and historical trends. Applied Geochemistry, V. 10, pp. 175-195.

Gearing, J. N., Buckley, D. E. and Smith, J. N. (1991) Hydrocarbon and metal contents in a sediment core from Halifax Harbour: a chronology of contamination. Canadian Journal of Fisheries and Aquatic Sciences, V. 48, pp. 2344-2354.

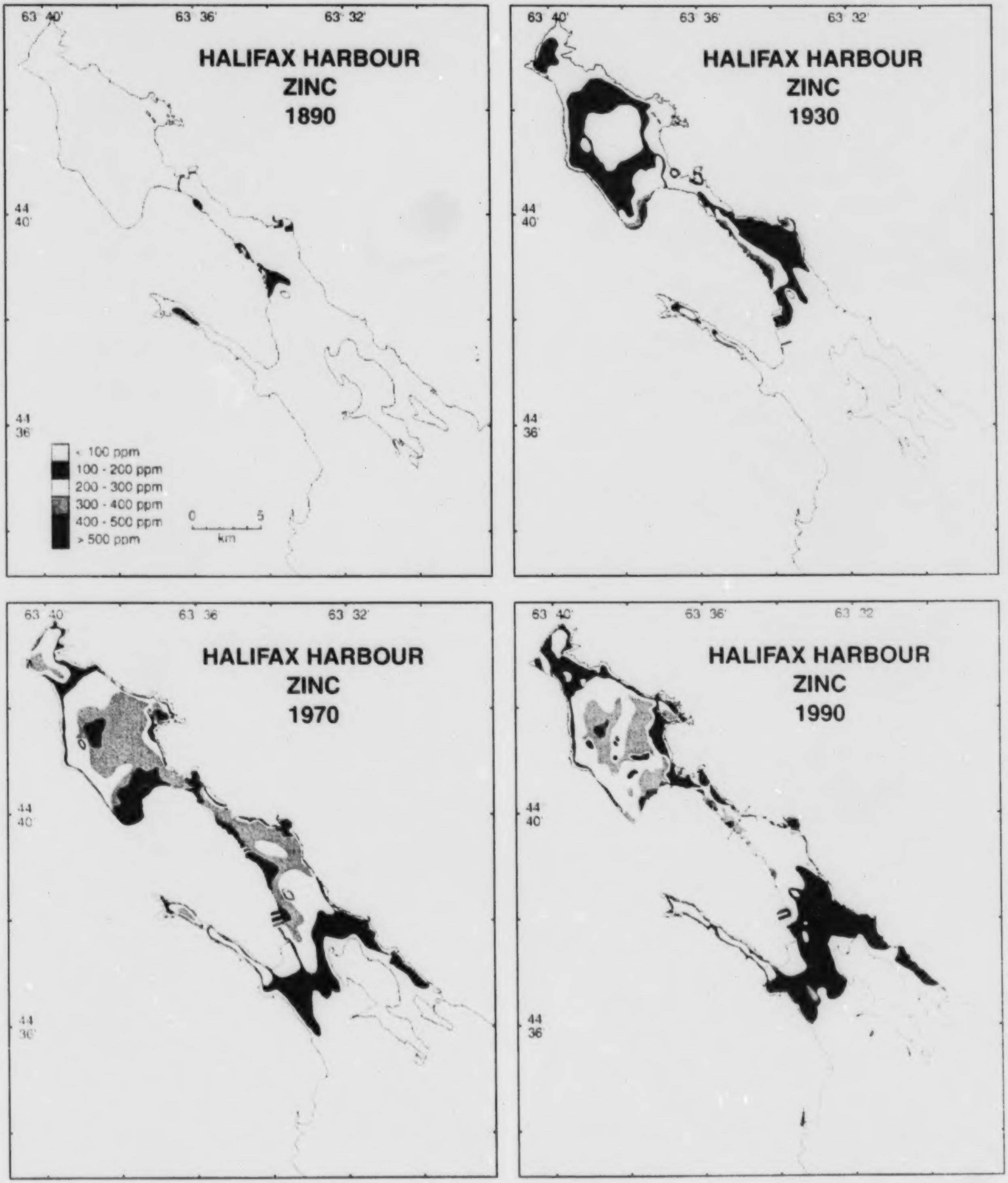


Figure 1. Zinc in sediments of Halifax Harbour as measured in dated sediment cores.

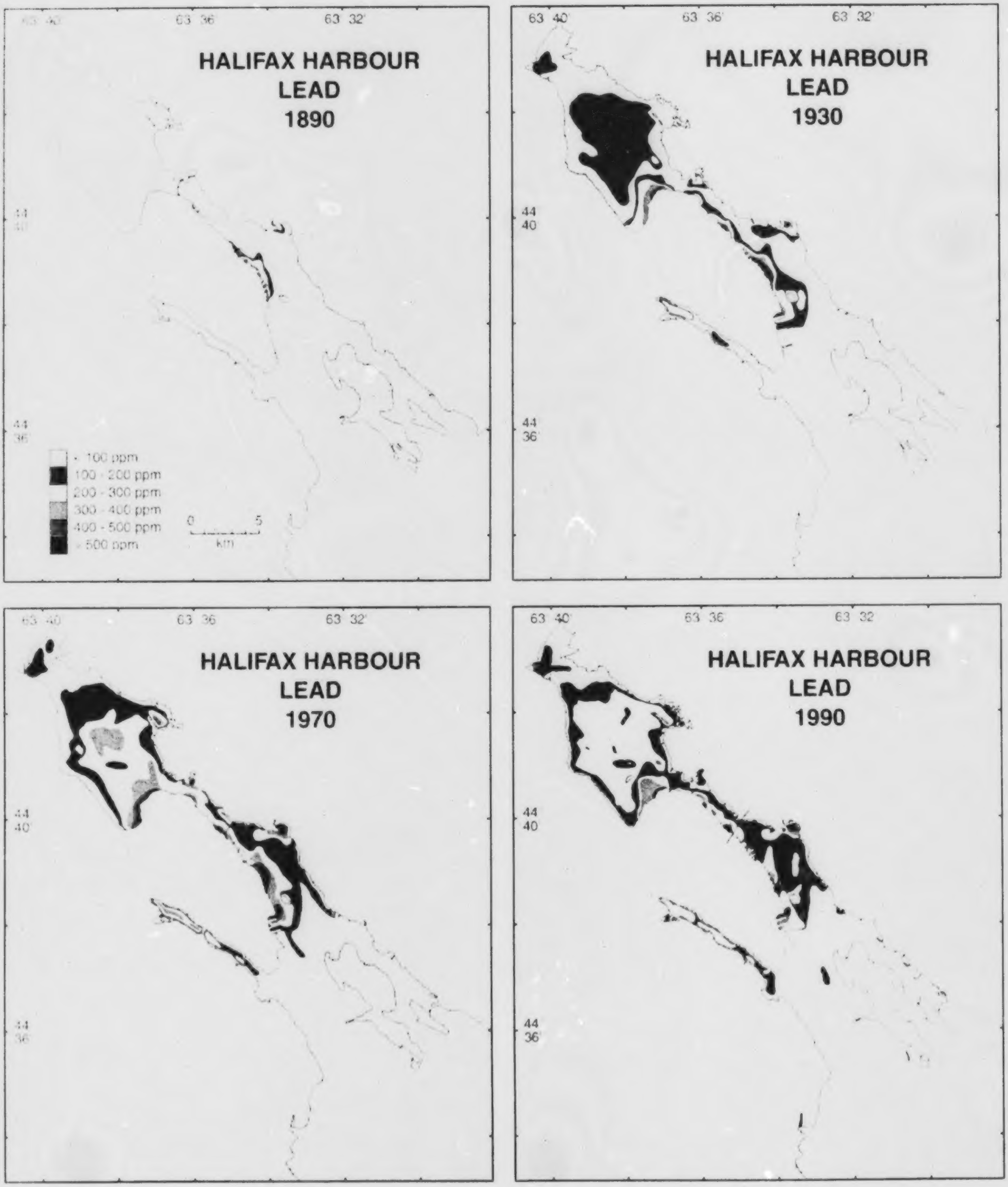


Figure 2. Lead in sediments of Halifax Harbour as measured in dated sediment cores.

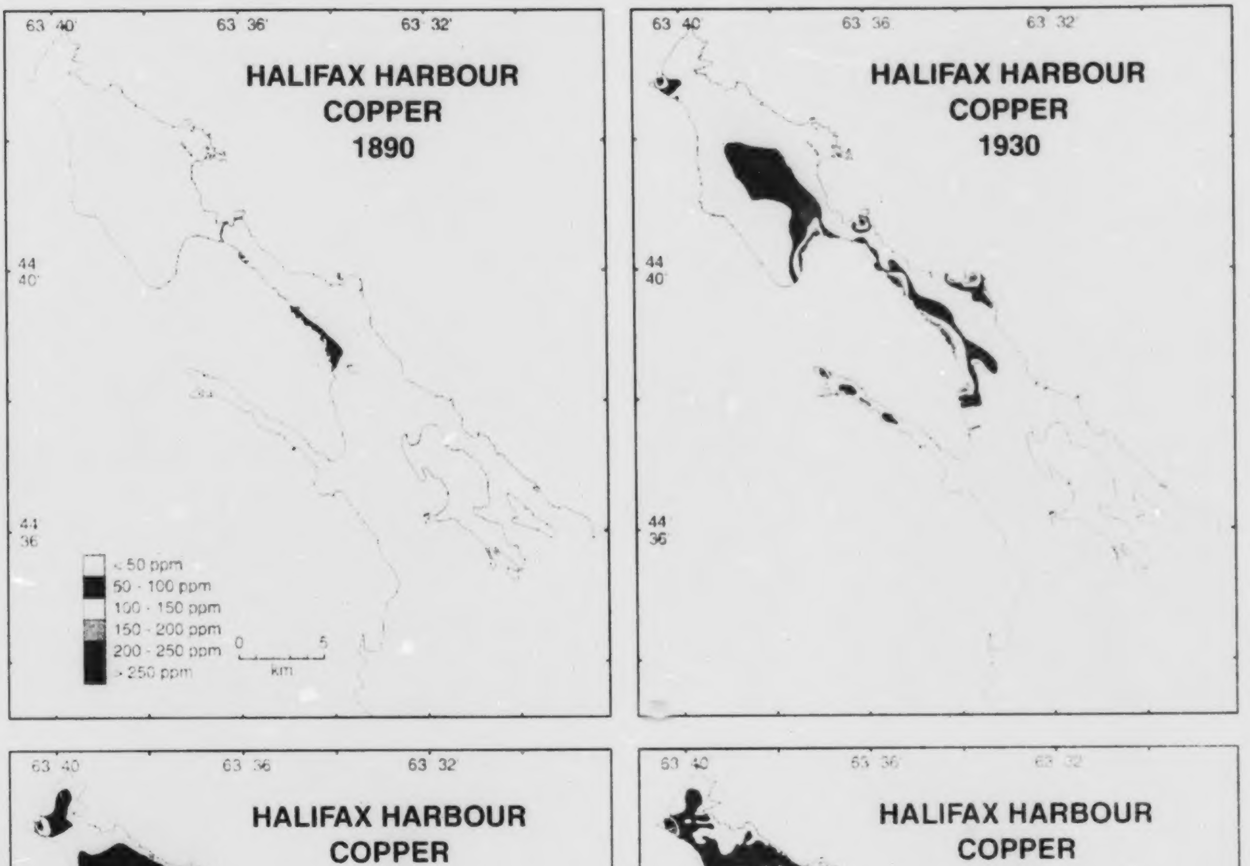


Figure 3. Copper in sediments of Halifax Harbour as measured in dated sediment cores.

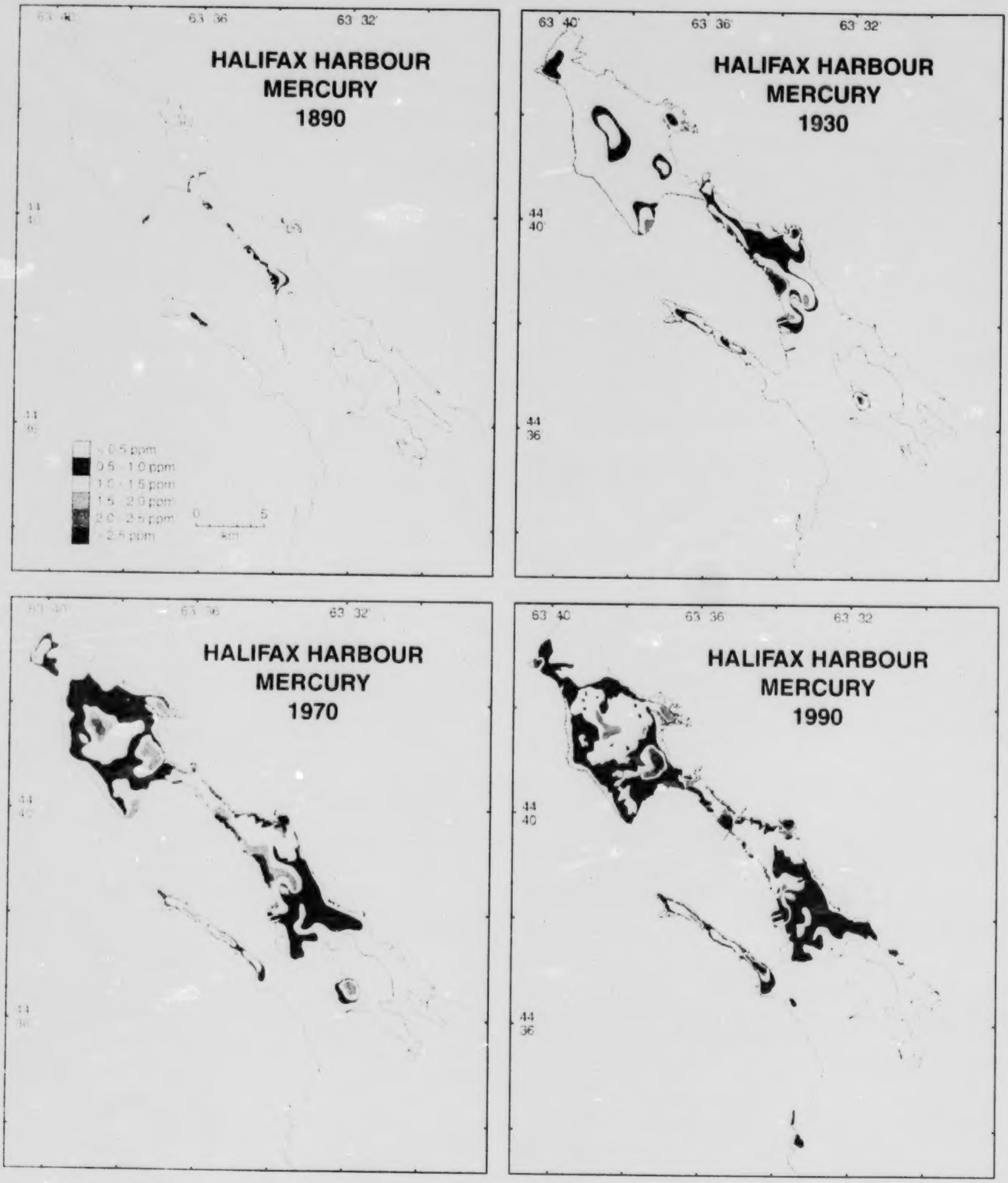


Figure 4. Mercury in sediments of Halifax Harbour as measured in dated sediment cores.

Contaminants in Halifax Harbour

Phil Yeats

I have two objectives in putting together this presentation. First, I want to describe some of the results produced by the Marine Chemistry Section at BIO on contaminant concentrations in Halifax Harbour, predominantly in water and biota, in the decade since the flurry of activity associated with the 1987 Harbour clean-up agreement. Much of this initial work was reported in Nicholls (1989), and numerous other papers in the 1989-1992 period. The literature produced at this time generated very few results on contaminants in water or biota. Secondly, I want to describe current activities in our laboratories related to contaminants in Halifax Harbour. Most of this work is related to transport and fate of the contaminants, and/or biological effects of contaminants.

In the past decade we have generated data sets on polyaromatic hydrocarbons (PAHs) and polychlorobiphenyls (PCBs) in Halifax Harbour lobster (digestive glands) and mussels. We have also conducted a study on PCBs in water and suspended particulate material in Bedford Basin, and provided some additional data on organic contaminants in sediments. Finally, we have expanded significantly the limited measurements of contaminants in dated sediment cores, focussing on areas in the Harbour where disturbance of the cores is a minimum.

The measurements of organic contaminants in lobster digestive glands (Figure 1) show a general decrease in concentrations from the more industrialized central harbour out to the Thrumcap Shoal area. Although the concentrations of both PCB and PAH in the harbour are substantially elevated compared to more pristine reference sites in non-industrialized N.S. harbours, the PCB levels do not exceed the allowable limit for consumption of fish products and PAH levels are much lower than those observed in Sydney Harbour where the fishery was closed because of PAH contamination. They could still, however, be high enough to cause biological effects on these or other organisms in the Harbour. Figure 1 only shows the concentrations of total PCB and total PAH, however, here and in all of our other studies, a broad range of individual compounds were analysed. The analytical procedure looks for 159 separate PCB congeners and up to 33 different PAHs.

Mussel samples collected at 18 sites around the harbour on three occasions from 1997 to 1999 have also been analysed for PAHs (Hellou et al., 2000) and PCBs. The concentrations show a lot of temporal and spatial variability (Figure 2). Whether this variability is caused by changes in the source strength for the contaminants, changes in mussel physiology, some combination of the two, or something else entirely is unclear at the moment. Overall concentrations of PAHs in mussels are similar to those in lobsters, PCB concentrations are lower.

Dissolved and particulate PCB concentrations were measured in 1996 and 1998 during the spring phytoplankton bloom in Bedford Basin. The data were collected to investigate the importance of the bloom in terms of regulating the distribution of PCBs between dissolved and particulate phases. The results for 1996 (Figure 3) show a decrease in dissolved PCB concentrations throughout the experiment and increases in particulate PCB coincident with increases in phyto-plankton. The 1998 results are similar.

One of the most interesting aspects of all of these PCB studies has been the occurrence of 3,3'-dichlorobiphenyl (PCB#11). This compound, which is not found in any of the Aroclor mixtures, nor produced by the decomposition of any Aroclor PCBs, is found at varying concentrations in all of our water and biota samples. It was also found in the sediment sample collected in Tufts Cove, but not in other sediment samples. PCB#11 would appear to be introduced into the Halifax Harbour marine environment from a specific non-Aroclor source.

As indicated earlier my, second objective is to describe current activities in our lab related to contaminants in Halifax Harbour. Most of this work is related to transport and fate of the contaminants, and/or biological effects of contaminants. The focus here is on the importance of the chemistry of the contaminants and how the chemical speciation and reactions that occur in the marine environment affect both the transport/fate and the toxicity of the contaminants. We are currently in the first year of a three year project, so there are few results to describe at present.

One component of the project is designed to investigate the differential transport of organic contaminants (PAHs and PCBs) to mussels and sediments, two important transport pathways for these hydrophobic contaminants. The focus will be on investigating the variability in exposure (source strength) and its impact on organic contaminant concentrations in the mussels and biological effects. To this end, water, suspended matter and mussel samples are being collected monthly for organic contaminant analysis and biological effects measurements. Identifying a sewage tracer in mussels is another important part of this investigation.

Another component is looking at the effect of chemical speciation of copper on copper toxicity to phytoplankton. Copper is toxic to phytoplankton at concentrations far below the harbour's observed total dissolved copper concentrations. The toxicity is mitigated by the complexation of copper with organic ligands - only free ionic copper is toxic. But the ligands and the extent of complexation will change from sewage to seawater. These changes in complexation are being measured and the effects on toxicity to phytoplankton are being investigated.

The rest of the project is oriented towards the sediments. Historical changes in the fluxes of contaminants to the sediments are being measured using radio-chemically dated sediment cores and changes in sediment toxicity over time are being measured. Toxicity identification evaluation protocols (TIE) are being used to link the toxicity with the principle contaminants responsible for the toxicity. The identified principle toxicants will be the focus of sediment toxicity studies. Laboratory experiments exposing amphipods to contaminated sediments will be one of the tools used to investigate bioavailability and toxicity of sediments.

Finally, biogeochemical models will be used to tie this all together. An environmental quality model that incorporates partitioning between dissolved and particulate phases is being constructed to describe contaminant transport in the Harbour. Modelling will be used to predict the future course of contamination and the consequences of changes expected from the implementation of sewage treatment and other remediation measures.

References:

Hellou, J., T. King and D.E. Willis. 2000. Seasonal and geographical distribution of PAHs in mussels, Mytilus edulis, collected from an urban harbour. Polycyclic Arom. Compds., 20: 21-38.

Nicholls, H.B. (ed). 1989. Investigation of marine environmental quality in Halifax Harbour. Can. Tech. Rep. Fish. Aquat. Sci., #1693, 83 pp.

Figure 1

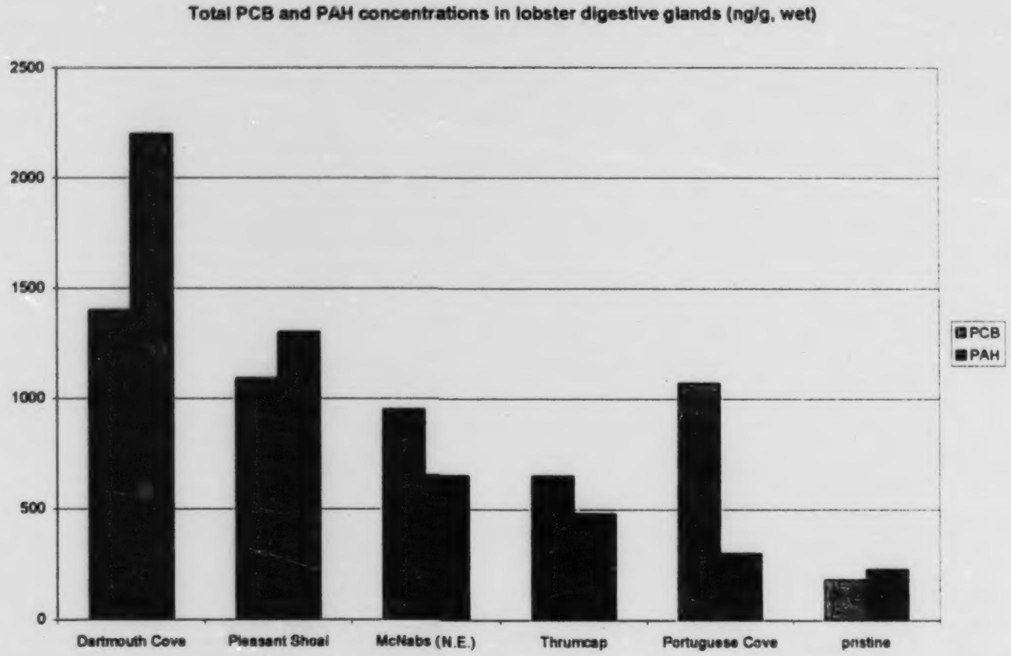


Figure 2

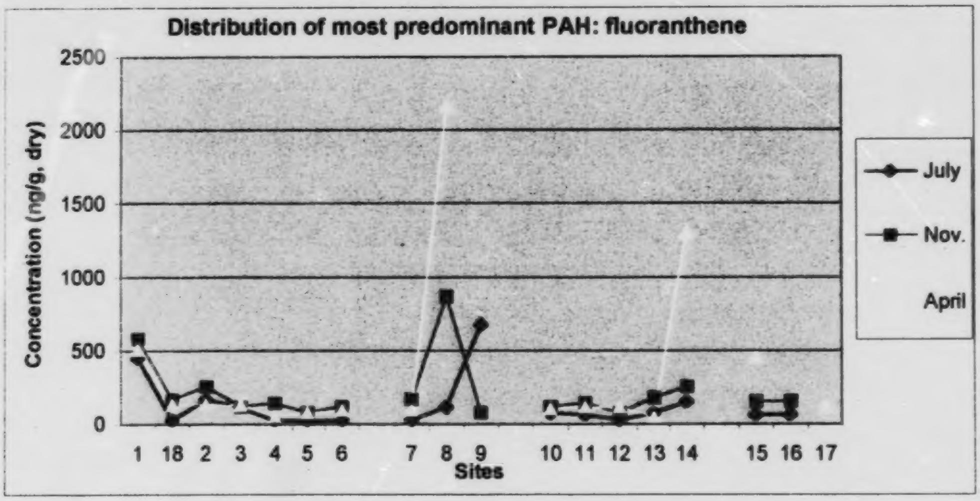
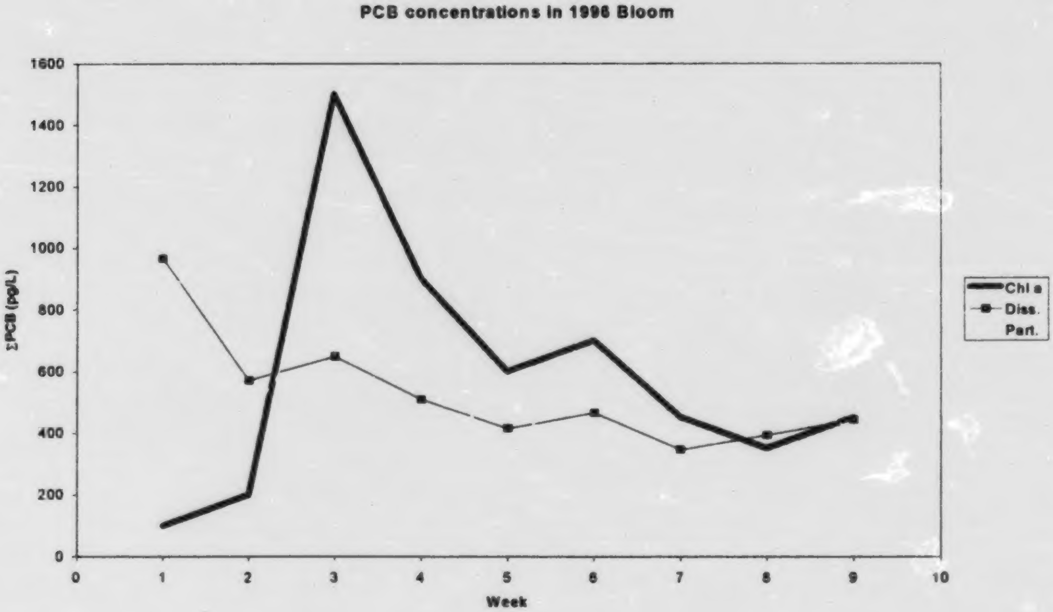


Figure 3



Halifax Harbour: The Geology and Evolution of Marine Habitat

Gordon B. J. Fader

"Geological Survey of Canada, Contribution No. 2000298"

INTRODUCTION

The most recent study of the marine geology of Halifax Harbour was undertaken between 1988 and 1994 when a program of extensive surveys was conducted with a variety of remote sensing geophysical tools and geological sampling equipment. These studies have been summarized in numerous Open File Reports of the Geological Survey of Canada (GSC) and in the published literature (Fader and Petrie, 1991, Fader et al., 1991, 1994, 1996, 2000b, Courtney and Fader, 1994, Fader, 1992, 1995, 2000, Miller and Fader, 1995, Fader and Buckley, 1997, Lewis et al., 1996 and Edgecombe et al., 1999). A geoscience synthesis GSC Bulletin is in prep., (Fader and Miller, in prep.). The reader is referred to these publications for a description and distribution of sediments, bedrock, seabed and subsurface natural and anthropogenic features, geological history and associated processes.

The purpose of this paper is to present a brief summary of the geological history of Halifax Harbour with an emphasis on the history of development of present seabed characteristics. This is followed by a discussion of a strategy to assess and map benthic habitats for comprehensive environmental management.

GEOLOGICAL HISTORY

Pre Glacial Origin of the Harbour

Earliest accounts of the formation of Halifax Harbour attributed its origin to the presence of northwest-southeast structural lineaments (faults) (Cameron, 1949). It was suggested that the faults may have been zones of weakness for later preferential erosion by pre-glacial rivers, glacier ice and meltwater. There is very little evidence for the presence of large faults beneath the Harbour as the major synclines and anticlines on either side of the Harbour appear aligned without offset, and this evidence is supported by aeromagnetic data showing structural continuity of anomalies. Sidescan sonar and multibeam bathymetric images of bedrock show no recognizable faults or offsets within the areas of exposed bedrock on the seabed. Halifax Harbour therefore owes its origin not to the presence of faults in bedrock, but to the distribution of bedrock type, namely, the dominant presence of the eastern flank of the South Mountain Batholith to the west of the Harbour (Fader, 2000). This large, erosion-resistant granitic intrusion confined the location of fluvial drainage systems in preglacial time to weaker metasedimentary rocks east of the batholith.

King (1970) mapped a channel off the mouth of Halifax Harbour to the east of the batholith. He proposed the term "Ancient Sackville River" for this feature. It is clearly present on the multibeam bathymetric image off Halifax Harbour although its width is considerably less than originally interpreted.

An ancient pre-glacial Sackville River likely flowed through the area of Bedford Basin, the Harbour and across the inner Scotian Shelf (Figure 1) but the presence of a deep inner Harbour subsurface basin (Figure 2) suggests another smaller drainage system from

Dartmouth Cove that joined with the Sackville River in the inner Harbour north of Georges Island. Therefore, it is likely that two early drainage systems contributed to the preglacial formation of Halifax Harbour.

Glacial History

Before Pleistocene glaciation, which began approximately 2.5 million years ago, Bedford Basin did not exist. The Ancient Sackville River continued on its course across the gently dipping Cretaceous peneplain of the Atlantic Uplands physiographic province, through the present area of the Basin, and out of the Harbour along the outer western flank. With the onset of glaciation, glaciers eroded and overdeepened the area of Bedford Basin by more than 50 m. Research on the relative effects of multiple glaciations of Atlantic Canada (Piper and Normark, 1989) suggests that the greatest erosional event took place during the Illinoian glaciation, prior to the last glaciation, the Wisconsinan.

The most extensive overdeepening of the harbour occurred in the buried basins, where lacustrine/estuarine sediments are presently located (Figure 2). As a result of the glacial overdeepening of Bedford Basin, a continuous river channel for the Ancient Sackville River ceased to exist. The term "Lake Bedford" is proposed for this early lake. At The Narrows, a new outlet formed for drainage from the ancient Sackville River and Lake Bedford.

Glacial Control on Harbour Morphology

As glaciers moved through the Harbour, variations in bedrock lithology and structure largely controlled the amount of erosion, developing the width and morphology of the present Harbour. As the ice moved across the Halifax Formation (Fader, 2000) it was not able to remove large blocks of material as readily as it could over the Goldenville Quartzite. The widely-spaced fractures and thick beds of the Goldenville Formation made it more susceptible to glacial block quarrying while the Halifax Formation, with thinner more closely-cleaved beds, allowed only limited glacial removal and the generation of smaller fragments. Therefore, glaciers eroded much less material from the Halifax Formation.

Wisconsinan Glaciation

Glaciers likely occupied the area of Halifax Harbour many times beginning in the middle Pleistocene, but most of the surficial materials overlying bedrock and the present glacial landforms are interpreted to relate to the last major episode of glaciation, the Wisconsinan.

The oldest terrestrial Quaternary sediments recognized in Nova Scotia are the Bridgewater and Mabou conglomerates. They are iron-cemented drift composed of slate and granite clasts that lie below tills and over striated bedrock. Their age and origin is uncertain, and some consider them to be of Tertiary to early Pleistocene in age (Stea, 1978). They occur in areas around Halifax Harbour, particularly in the Northwest Arm, and likely lie beneath other areas of the Harbour bottom.

The last major period of glaciation began in Maritime Canada at about 75,000 yr B. P. during the early Wisconsinan. The ice sheet is interpreted to have extended eastward and southeastward to the edge of the Scotian Shelf. A tripartite stratigraphy to the tills offshore and onshore reflects changing ice centres in the Maritime region, collectively termed the Appalachian ice complex (Stea et al., 1998). Five glacier flow events are recognized representing separate phases evolving from shifting ice centres and divides.

These appear to have occurred without intervening nonglacial intervals (Stea et al., 1992). This first ice advance is interpreted to have deposited the Hartlen Till, a grey, matrix-rich and overconsolidated silty till that occurs in and around Halifax Harbour and is commonly found at the base of the surficial succession in drumlins. It is exposed at the base of cliffs along the shoreline of Eastern Passage.

Ice likely retreated to the inner Scotian Shelf during the Mid-Wisconsinan Phase, 40-22 yr B.P. During this time the area of Halifax Harbour is interpreted to have remained under ice cover. This was followed by the Escuminac Phase of the Late Wisconsinan, 22-18 ka, with an advance of ice centered over the Magdalen shelf in the Gulf of St. Lawrence (Stea et al., 1998). The glacial ice also transported and deposited large quantities of red hematitic till to the shelf edge. This till is termed the Lawrencetown Till, which is a silty-till with a sharp contact, often defined by boulder rich horizons, with the underlying grey Hartlen till. The Lawrencetown Till contains more clay than the underlying Hartlen Till and is less compact. This ice formed drumlins on the floor of Halifax Harbour, as well as the many drumlins of the surrounding land areas such as Citadel Hill and McNabs and Lawlor Islands.

By 18 ka, Late Wisconsinan ice began to calve and retreat back across the Scotian Shelf, sometimes constrained at bedrock highs that controlled the deposition of moraines. The Scotian Phase followed and resulted in a major change in ice centre locations as a result of ice stream drawdown into the deep areas surrounding Nova Scotia such as the Bay of Fundy and Laurentian Channel.

On land, striae suggest a southeastward flow in the area of Halifax Harbour. The till deposited during this phase is a stony, sandy till, derived from local bedrock sources with a high percentage of angular boulders. It has been termed the Beaver River Till from a type section in southwest Nova Scotia (Grant, 1980; Finck and Stea, 1995). This till overlies both the Lawrencetown and Hartlen Tills in drumlins and forms a bouldery till plain over most areas of the Atlantic coast including Halifax Harbour. The Beaver River Till was formed during the time period of 17,000-15, 000 yr B.P.

By 13 000 yr B.P. the ice margin was situated near the present day Atlantic coast of Nova Scotia. These small glaciers further retreated landward with probable reentrants up some of the larger embayments. As the glacial ice retreated up Halifax Harbour, small linear moraines parallel to the ice front formed in the inner Harbour northeast of Georges Island, and in Bedford Bay where they remain as bouldery ridges. They represent ice-marginal deposits which formed as ice lifted off the seabed, and are similar to large fields of lift-off moraines which are found west of the entrance to Halifax Harbour and across the Scotian Shelf (King and Fader, 1986). The climate warmed considerably during this period and the glaciers shrank to a series of small terrestrial centres in Nova Scotia leaving deposits of hummocky ground moraine as they ablated by downwasting (Grant,1977).

A well-developed low sea level stand has been identified on the inner Scotian Shelf off Halifax at a depth of between 65 and 70 m at 11.7 ka (Stea et al., 1994). This former shoreline is defined on the basis of major changes and distributions in terrane character, seabed features and sediment textures. Relative sea level quickly rose after 11.6 ka transforming areas above 65 m water depth into a low relief surface of gravel lag, bedrock outcrop and limited areas of well-sorted coarse sand devoid of silt and clay. Former drumlins were severely eroded into low-relief bouldery ridges.

Between 11,000 and 10,000 yr B. P. the climate of Nova Scotia cooled which greatly affected the land and marine areas. Both lake and offshore sediment cores show a distinct coarsening that marks the Younger Dryas period during which land-based glaciers were reactivated.

Post Glacial History

With final removal of glacial ice, the area of Halifax Harbour existed as a series of lakes in Bedford Bay, Bedford Basin, Fairview Cove, the inner Harbour around Georges Island, the Northwest Arm, Eastern Passage, east of McNabs Island, off Herring Cove and in an area extending from Portuguese Cove to Chebucto Head (Figure 2). These were connected by a series of rivers and streams cutting through bedrock-dominated sills separating the lakes.

Boulder berms formed in some of these lakes as the result of seasonal freezing and ice expansion, and remain exposed at the present seabed in Bedford Basin and in the area between McNabs Island and Pleasant Shoal south of Halifax. The sill between Bedford Bay and Bedford Basin, Wellesley Ridge, is a series of essentially continuous bedrock ridges that suggest the existence of water falls along the course of the early rivers. The Bedford Bay sill displays a small bedrock notch on multibeam bathymetry that locates an ancient waterfall (Figure 3).

Continuous bedrock ridges that cross the Harbour in The Narrows also indicate that local waterfalls and isolated small ponds or lakes could have existed. A prominent, partly-exposed, section of the former Ancient Sackville River occurs in the southern part of The Narrows where it is well-defined on the multibeam bathymetry (Figure 4). This segment is a sinuous channel suggesting formation by fluvial processes.

The early marine Halifax Harbour was confined to a narrow channel in the western outer Harbour, as the present major shoal areas were emergent until approximately 7000 years B. P. As sea level continued to rise, intense erosion occurred in the outer Harbour. The present bedrock shoal areas east of the western deep channel were subjected to large waves at the shoreface. Most of the till was eroded from these areas leaving only scattered boulders on bedrock. During the transgression of the outer Harbour, sand-sized material was transported and deposited in the deep channel of the western outer Harbour where it remains today. Fine-grained muds were transported farther seaward to the northern part of the basins of the inner shelf. The marine transgression continued to migrate up the Harbour with the formation of the Sable Island Sand and Gravel overlying bedrock, till, lacustrine and perhaps glaciomarine sediments. Where the transgression breached sills and flooded former lakes, Sable Island Sand and Gravel deposition was thin or absent.

In contrast to the effective erosion by the transgression in the outer Harbour, erosion was much less severe in the inner Harbour as a result of sheltering by McNabs and Lawlor Islands, the narrowing of the entrance of the inner Harbour between McNabs Island and Halifax Peninsula, and the increasing distance from the open Atlantic Ocean. In many places tills were preserved and only their upper surfaces were modified. Fine-grained sediments were winnowed and lag surfaces of angular clasts were formed.

The pre-existing Harbour lakes were inundated with marine waters as their sills were successively breached and overstepped. In The Narrows, beach processes were more intense, perhaps as a result of the longer fetch up the Harbour and funneling effects of both narrowing and shallowing. Curvilinear boulder berms were formed at successively shallower depths until the sill at the junction with Bedford Basin was finally breached at 5800 yr B. P.

The earliest deposition of LaHave Clay (clayey silt) in the inner Harbour occurred at approximately 5500 yr B. P. overlying transgressed surfaces and deposits of Sable Island Sand and Gravel. Much of the deposition of LaHave Clay took place under conditions and in areas similar to the present. Non-depositional moats formed early around Georges Island and in other areas, indicating that oceanographic conditions were similar to those at present. Minor variations in depositional patterns and fining-upward textures suggest stronger currents in early LaHave Clay time which is to be expected under shallower water conditions. Within the LaHave Clay, degradation of organic material took place leading to the generation of methane gas and the development of gas-charged zones. These occurrences are extensive over areas of the inner Harbour including Bedford Basin, the Northwest Arm and Eastern Passage.

As the water depths became deeper in the outer Harbour, gravel surfaces became more stable. By approximately 3000 years B. P., when sea level had returned to within 5 m of its present position, modern conditions had largely developed in the Harbour. Estuarine circulation was well-established largely driven by the Sackville River, with the dominant movement of water in at the bottom and out at the surface. The seabed sediments of the outer Harbour were periodically affected by large storms and waves with the development of sand ribbons, megaripples, ripples in gravel and gravel circles. Energy conditions interpreted from bedforms in the outer Harbour indicate a consistent decrease with distance up Harbour from Chebucto Head.

The area of Sandwich Point is a critical transitional zone for both sediment type and seabed processes. Here the mud of the inner Harbour terminates in a complex distribution with the development of sedimentary furrows. These bedforms indicate both periodic deposition of fine-grained materials sourced from the north and intermittent erosion with transport of sand to the north in response to strong storm generated currents from the south.

RECENT CHANGES

With the founding of Halifax Harbour in 1749, the Harbour seabed and coastline began a new phase of alteration, largely driven by anthropogenic activities of land clearing, waste disposal and shipping. These earliest activities were initiated with the anchoring of ships in the Harbour which produced distinctive patterns of erosional marks on the seabed (anchorturbation). This activity continues today in a more intense way, as bigger ships and much larger anchors are involved. Disturbance and resuspension of sediments by propellers also occurs. Some vessels sunk as a result of storms, collisions, and fire, and over 30 vessels or large parts of vessels have been identified on the Harbour floor.

Early settlers built docking facilities and began the process of infilling areas of the waterfront for a variety of shipping, construction and industrial activities. This has continued to the present day with the construction of container piers, housing developments and waterfront commercial and tourism facilities. A major breakwater was constructed shortly after 1913 in south Halifax which constricted the main channel into the inner Harbour by one third. It was built to a shallow bedrock ledge called Reed Rock and provided a sheltered area for the boat basin of the Royal Nova Scotian Yacht Club. Scoured depressions in the LaHave Clay offshore from the breakwater may have formed or been overdeepened as a result of this process of Harbour narrowing and resultant increased current velocity.

The two World Wars and associated military activities have had a dominant influence on the seabed of the Harbour. Large convoys of ships assembled in the Harbour and Bedford Basin before leaving for Europe. These ships anchored over large areas, eroding and mixing sediments as well as discharging materials to the seabed. Submarine detection and destruction devices were placed in the outer Harbour and were connected with electrical transmission cables, some of which remain on the Harbour seabed. Anti-submarine nets were strung across areas of the Harbour to control the passage of submarines. Remains of these structures are still present on the Harbour bottom. Recent military activities include the emplacement of acoustic and magnetic sensors on the seabed. Dredging and seabed foundation preparations are associated with these activities.

Dredge spoils have been dumped to the seabed, particularly in Bedford Basin. They contain a wide variety of materials ranging from construction debris to dredged sediments from other areas. To enhance the shipping related activities in the Harbour, areas were dredged, docks were constructed and several shallow areas including drumlins and bedrock outcrop were blasted and dredged for safer vessel transit. Seabed mining for aggregate took place to the north and east of McNabs island.

Major recent engineering projects, such as the construction of the two bridges spanning The Narrows and the container terminals, have infilled large areas of the Harbour and changed conditions that affect the present and future deposition of sediments. The Halifax Explosion, the worlds largest manmade explosion prior to the atomic bomb, took place in The Narrows. It however, only altered the seabed in a minor way (Fader, 1992, 1995). The majority of the damage was on land and the seabed was altered more by the post-explosion dredging efforts to remove debris for safe navigation and resumption of ship building activities.

Within Bedford Basin, the presence of three large depressed areas in the deep water part that resemble marine sediment slumps, are interpreted as recent subsidence depressions (Fader et al., 2000). The freshness of the en-echelon edges of the features, despite continued anchoring and sedimentation, supports the possibility that the activity continues. It is not know if the features are the result of methane gas venting, dewatering, or differential compaction.

Anthropogenic activities in the inner Harbour are the dominant processes which are presently affecting the distribution of sediments, their characteristics and seabed processes. This is in sharp contrast to the outer Harbour where highly energetic natural processes dominate along an exposed shallow Atlantic inner shelf.

MULTIBEAM BATHYMETRY

A relative newcomer to the tool kit of marine geologists, multibeam bathymetry was first applied to the Harbour in 1991 and helped immensely in the interpretation of seabed processes, particularly seabed erosion and deposition (Fader et al., 1996). In an evaluation of multibeam bathymetry in Halifax Harbour, in comparison to traditional approaches to geological surveying, Courtney and Fader 1994, concluded that the multibeam information of 100% seabed coverage was vital for connection and extrapolation of features interpreted from widely-spaced adjacent ship tracks. The ability to integrate oneself with multibeam data through virtual fly-throughs, the manipulation of vertical exaggerations and the application of artificial illumination, provided a powerful tool for a seabed process understanding. This however, does not apply to the subsurface, and traditional seismic reflection and core information is still required for a comprehensive understanding of the evolution of the Harbour.

Bedford Basin remained unsurveyed with multibeam systems until 1999 and an interpretation of the multibeam image from that area has recently been published (Fader et al., 2000) (Figure 5). Multibeam information can also be processed for backscatter (a correlated proxy for sediment type) and seabed slope.

HARBOUR INFORMATION GAPS

Despite all of the surveys of the Harbour, including those by other disciplines, two large gaps presently remain. These are a systematic assessment and mapping of sediment organic contaminants and a regional assessment of benthic communities and associated habitats. Although many spot observations have been made and specific areas targeted, there remains a lack of regional assessment in both these disciplines. I will address the knowledge base on benthic habitat and suggest an approach to fill this gap.

An important outcome of the application of multibeam bathymetry to issues of seabed mapping, stability, and process understanding by the geoscience community has been a realization of the value and connection of seafloor characterization to mapping of marine habitat, benthic communities, assessment of fishing practices, location of benthic species of commercial value, the design of fishing practices to use multibeam information and the management of components of the fishery that rely on bottom information. Indeed, it is now accepted that to a large degree, the future of successful sustainable management of the Canadian offshore requires an understanding provided by multibeam bathymetry and its derived and interpreted products. This has led to a drafting of the SeaMap proposal, an ambitious plan to systematically map the offshore areas of Canada with this new high-resolution seabed characterization technology. The outcome of the project, if supported, will be a suite of mapped and interpreted digital products that depict morphology, seabed sediment type, seabed dynamics and benthic habitats. For clarity, the definition of seabed habitat as used by the marine geological community includes the non-living environment of the seabed such as relief, structure, shape, materials, and processes which support life.

HABITAT ASSESSMENT

We can use the methods of habitat assessment as defined in Todd et al., 1999, Kostylev et al., in press and Fader et al., 2000a as a model to be applied to Halifax Harbour to fill the gap in understanding and mapping benthic habitat and associated living communities. Presently within the marine biological community there are no broad-area remote sensing tools to define and map soft-bodied marine benthic organisms. Some success has been achieved in areas where dense bioherms of highly and uniquely reflective mussels exist (Wildish and Fader, 1998), and with bottom classification systems using echosounder signal processing techniques, but in general, the high water content and lack of acoustic impedance contrast against a highly reflective background of gravel or rock makes remote recognition of benthic organisms difficult using acoustic instruments alone. Therefore, biologists routinely rely on camera, video and sample observations for mapping purposes. These methods have limitations in that they are largely spot or transect measurements which are time consuming and costly. A large variety of excellent tools have been devised for these purposes and include systems such as Campod, Towcam and Videograb (Gilkinson et al, 1999).

It is in the area of benthic community/geological correlation that the major benefits of multibeam systems come into play for habitat characterization. The images derived from the multibeam systems are similar in many ways to aerial photographs of the adjacent land whereby the morphology of the terrain is presented and materials and processes can be discerned. Underwater, the multibeam images portray additional information on backscatter which is similar to spectral imagery from satellite data. Thus, the multibeam imagery and its derived and interpretive products can form the basis for habitat characterization and extrapolation of benthic observations from spot locations to regional areas.

The findings of Kostylev et al, (in press), demonstrate that the diversity, distribution and abundance of megafauna can be successfully predicted from interpretation of multibeam data that defines sediment type, distributions and habitat structure over a wide range of scales. With this understanding, a sample program to map the benthic communities living on and within the seabed environment of Halifax Harbour can be developed. Areas of consistent terrain, depth and character can be sampled with a minimal and effective suite of samples and the results can be extrapolated to terrain boundaries. Unique morphological, textural, feature or slope areas can be focused upon with denser grids of samples. Using this approach, a first-order understanding of the benthic communities in Halifax Harbour can be achieved in an efficient and cost effective manner. This does not take into consideration other factors such as temperature, salinity, nutrients and circulation which can also modify the benthos/sediment relationship.

Based on the geological mapping of the seabed of Halifax Harbour, a geoscience framework is already in place on which to build an assessment of the benthic communities and associated habitats. An efficient sample program can therefore be designed to take advantage of this existing information. Such a project could fill one of the important missing gaps in an understanding of Halifax Harbour and thus form the basis for informed Harbour management decisions regarding protection, preservation and perhaps enhancement of the marine environment.

References

Cameron, H.L., 1949. Faulting in the vicinity of Halifax, Nova Scotia. Proceedings of the Nova Scotia Institute of Science. Vol XXII, Part 3.

Courtney, R. C. and Fader, G.B.J., 1994. A new understanding of the ocean floor through multibeam mapping: Science Review 1992 and 1993 of the Bedford Institute of Oceanography. Dept. of Fisheries and Oceans, p. 9-14.

Edgecombe, R.B., Scott, D.B. and Fader, G.B.J., 1999. New data from Halifax Harbour: paleoenvironment and a new Holocene sea-level curve for the inner Scotian Shelf. Canadian Journal of Earth Sciences, 36: 805-817.

Fader, G. B. J., Miller R. O., and Pecore, S. S., 1991. The Marine Geology of Halifax Harbour and Adjacent Areas (Volume 1 and 2, 23 pp. and 25 maps). Geological Survey of Canada Open File Report No. 2384.

Fader, G. B. J. and Petrie, B., 1991. Halifax Harbour-How the currents affect sediment distributions, In Science Review, 1988 and 1989. Edited by Thea. E. Smith, the Halifax Fisheries Research Laboratory, and the St. Andrews Biological Station, Scotia-Fundy Region of the Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada, B2Y 4A2, p. 31-35.

Fader, G.B.J., 1992. Did the 1917 Halifax Explosion form a crater on the floor of Halifax Harbour? Halifax Explosion 1917 Commerative Conference, St. Mary's University, Dec 3-6, 1992, Halifax, Nova Scotia.

Fader, G.B.J., 1995. The marine geological setting and seabed impacts of the 1917 explosion of the Mont Blanc in Halifax Harbour. GSC Open File #3045, 62p.

Fader, G. B. J., 2000. Geological and anthropogenic features of Halifax Harbour, in Preserving the Environment of Halifax Harbour, Workshop Sponsored by DFO and HRM, Workshop Proceedings No. 1, pg 28 –35.

Fader, G.B.J., Miller, R.O. and Pecore, S.S., 1994. Sample control, anchor marks, anthropogenic features and lacustrine sediments of Halifax Harbour. GSC Open File Report # 2958.

Fader, G.B.J. and Buckley, D.E., 1997. Marine geolgy and geochemistry in the environmental management of Halifax Harbour. In Environmental geology of urban regions. Special publication of the Geological Association of Canada, GeoText 3.

Fader, G.B.J., Miller, R.O. and Courtney, R.C., 1996. A geological interpretation of multibeam bathymetry: inner Halifax Harbour. GSC Open File Report # 3154, 1 Poster.

Fader, G.B.J., Pickrill, R.A., Todd, B., Courtney, R.C. and Parrott, D.R., 2000a. The emerging role of marine geology in benthic ecology. Science review, Bedford Institute of Oceanography, DFO.

Fader, G. B. J., Miller , R. O. and Craft, A., 2000b. Bedford Basin: An interpretation of seabed features, materials and processess based on geological, geophysical and multibeam surveys. GSC Open File # 3941, 1 Poster.

Fader, G. B. J. and Miller, R. O. (in prep.) The surficial geology of Halifax Harbour. Geological Survey of Canada Bulletin.

Finck, P. W. and Stea, R. R., 1995. The compositional development of tills overlying the South Mountain Batholith: Nova Scotia Department of Natural Resources, Mines and Minerals Branch Paper 95-1, 51 p.

Gilkinson, K.D., E. Kenchington, D.C. Gordon Jr., K MacIsaac, C. Bourbonnais, D. Roddick, S. Naidu, D.L. McKeown, W.P. Vass, G.B.J. Fader and M. Lamplugh, 1999. Banquereau hydraulic clam dredging experiment. Abstract and poster paper presented at the ICES/SCOR Symposium on the Ecosystem Effects of Fishing, Montpellier, France, 16-19 March 1999.

Grant, D. R., 1977, Glacial style and ice limits, the Quaternary stratigraphic record, and changes of land and ocean level in the Atlantic Provinces, Canada: Géographie et physique Quaternaire, v. 31, p. 247-260.

Grant, D. R., 1980, Quaternary stratigraphy of southwestern Nova Scotia: glacial events and sea-level changes: Geological Association of Canada and Mineralogical Association of Canada Guidebook, 63 p.

King, L. H. 1970, Surficial geology of the Sable Island map area, Marine Sciences Branch publication No 1, 16 p.

King, L. H., and Fader, G. B J., 1986. Wisconsinan glaciation of the continental shelf-Southeast Atlantic Canada: Geological Survey of Canada. Bulletin 363, 72 pp.

Kostylev, V. E., Todd, B. J., Fader, G. B. J., Courtney, R. C., Cameron, G. D. M. and Pickrill, R. A. in press, A new approach to habitat mapping from Browns Bank, Scotian Shelf. Ecology Progress Series.

Lewis, C.F.M., Taylor, B.B., Stea, R.R., Fader, G.B.J., Horne, R.J., MacNeil, S.G. and Moore, J.G., 1996. Earth science and engineering urban development in the metropolitan Halifax region. GAC Special paper in Urban Geology of Canadian Cities. Edited by P.F. Karrow and O.L. White. P 409-444.

Miller, R.O. and Fader, G.B.J., 1995. The bottom of Halifax Harbour. GSC Open File Report #3154, 1 Poster.

Piper, D.J.W. and Normark, W.R, 1989. Late Cenozoic sea-level changes and the onset of glaciation: impact on continental slope progradation off eastern Canada. Marine and Petroleum Geology, v. 6, p. 336-348.

Stea, R. R., 1978. Notes on the "Bridgewater Conglomerate" and related deposits along the Eastern Shore of Nova Scotia: Mineral Resources Division, Report of Activities, 1977, Nova Scotia Department of Mines, Report 78-1, p. 15-17.

Stea, R. R., Piper, D. J. W., Fader, G. B. J. and Boyd, R., 1998. Wisconsinan glacial and sea-level history of Maritime Canada and the adjacent continental shelf: A correlation of land and sea events, Geological Society of America Bulletin: July 1998; v. 110; no. 7, p. 821-845.

Stea, R. R., Boyd, R., Fader, G. B. J., Courtney, R. C., Scott, D. B., and Pecore. S. S., 1994: Morphology and seismic stratigraphy of the inner continental shelf off Nova Scotia, Canada: Evidence for a –65 m lowstand between 11,650 and 11,250 14C yr. B. P., Marine Geology, v. 117, p. 135-154.

Stea, R. R., Conley, H., and Brown, Y. 1992: Surficial Geology of the province of Nova Scotia ; Nova Scotia Department of Natural Resources, Map 92-3, Scale 1:500 000.

Todd, B., Fader, G.B.J., Courtney, R.C. and Pickrill, R.A., 1999. Quaternary geology and surficial sediment processes, Browns Bank, Scotian Shelf, based on multibeam bathymetry. Marine Geology, 162, pp.165-214, Elsevier

Wildish, D. and Fader, G.B.J. 1998. Pelagic - Benthic coupling in the Bay of Fundy. Proceedings of the 32nd European Marine Biology Symposium, Gothenburg, Sweden.

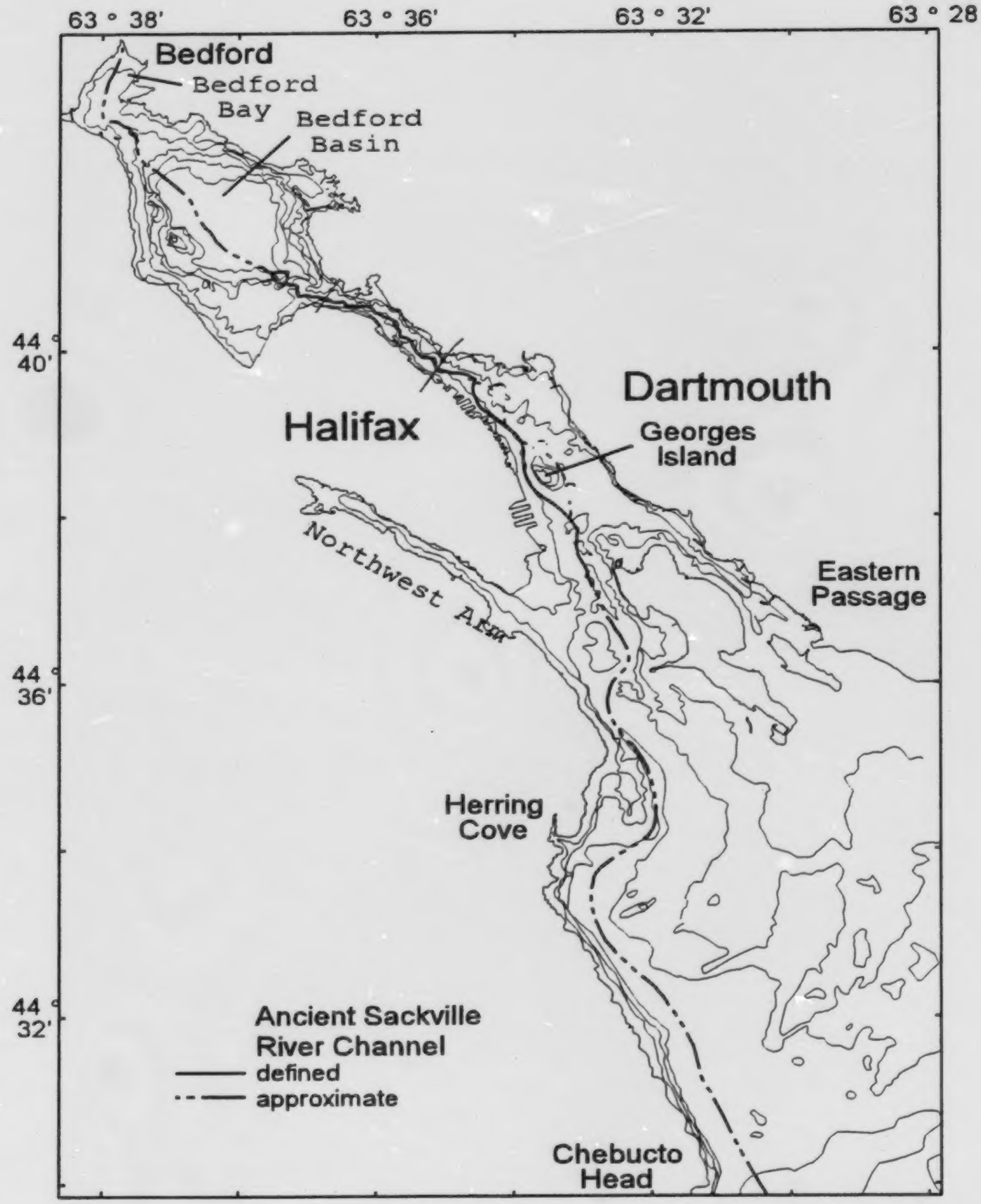


Figure 1: Interpreted pathway of the "Ancient Sackville River" through Halifax Harbour based on multibeam bathymetry and high-resolution seismic reflection profiles.

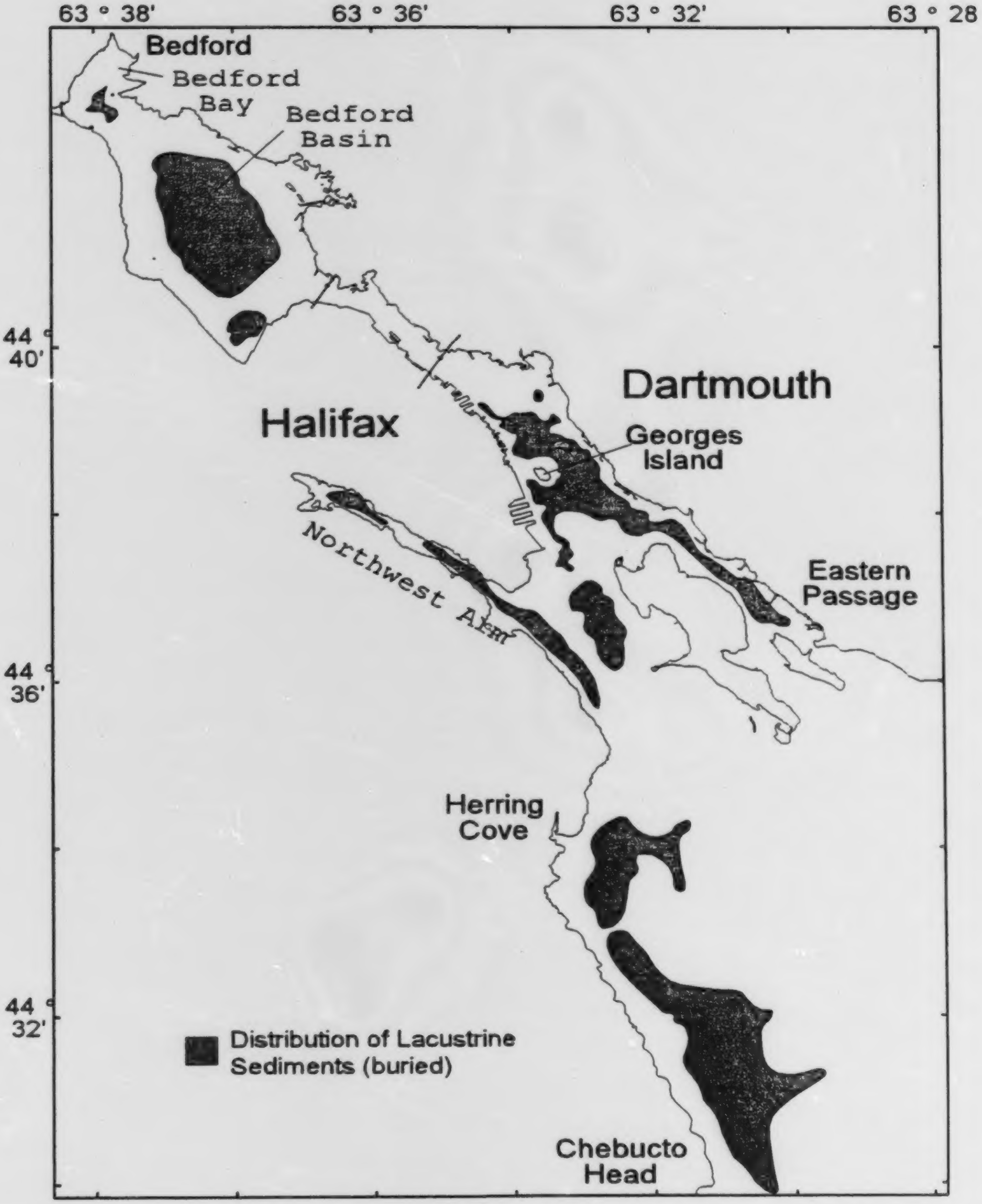


Figure 2: A map of the distribution of post glacial, pre-transgression lakes in Halifax Harbour.

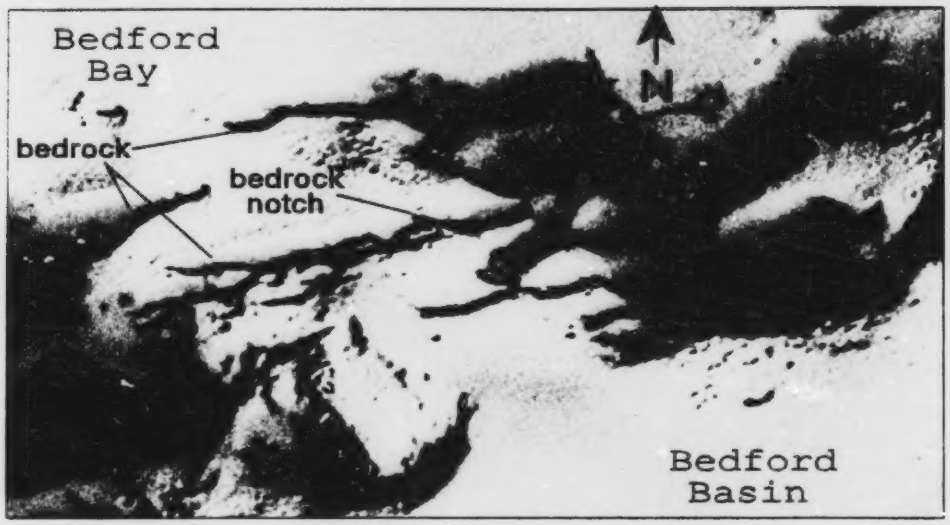


Figure 3: A multibeam bathymetric image from the sill area separating Bedford Basin from Bedford Bay artificially illuminated from the NW. bedrock notch occurs in the Goldenville Quartzite bedrock that was the location of a former waterfall when the Bay and Basin were lakes. This site represents a good potential location for the discovery of archaeological artifacts.

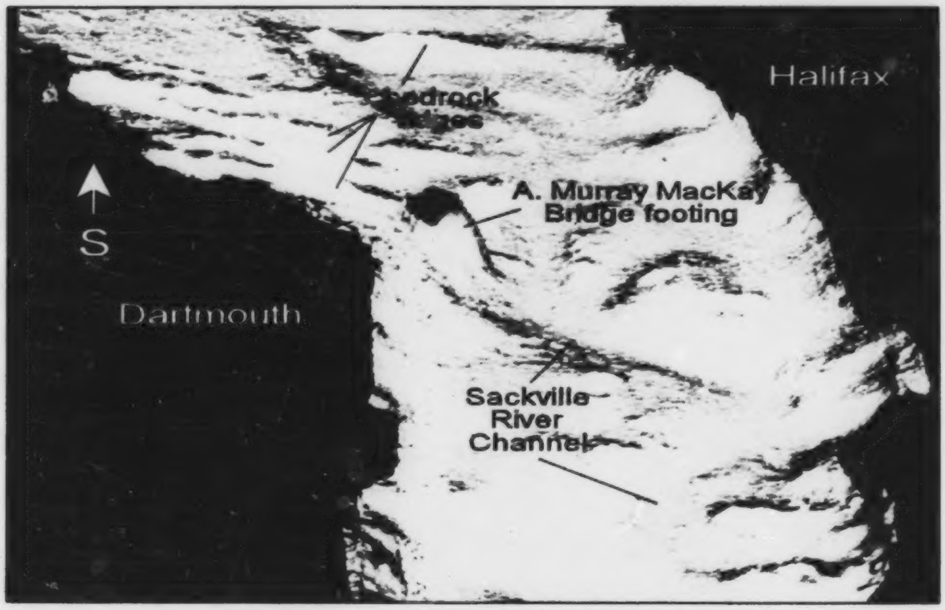


Figure 4: A 3-D perspective view from multibeam bathymetric data of The Narrows looking to the south. The curvilinear channel of the Ancient Sackville River can be seen on the seabed.

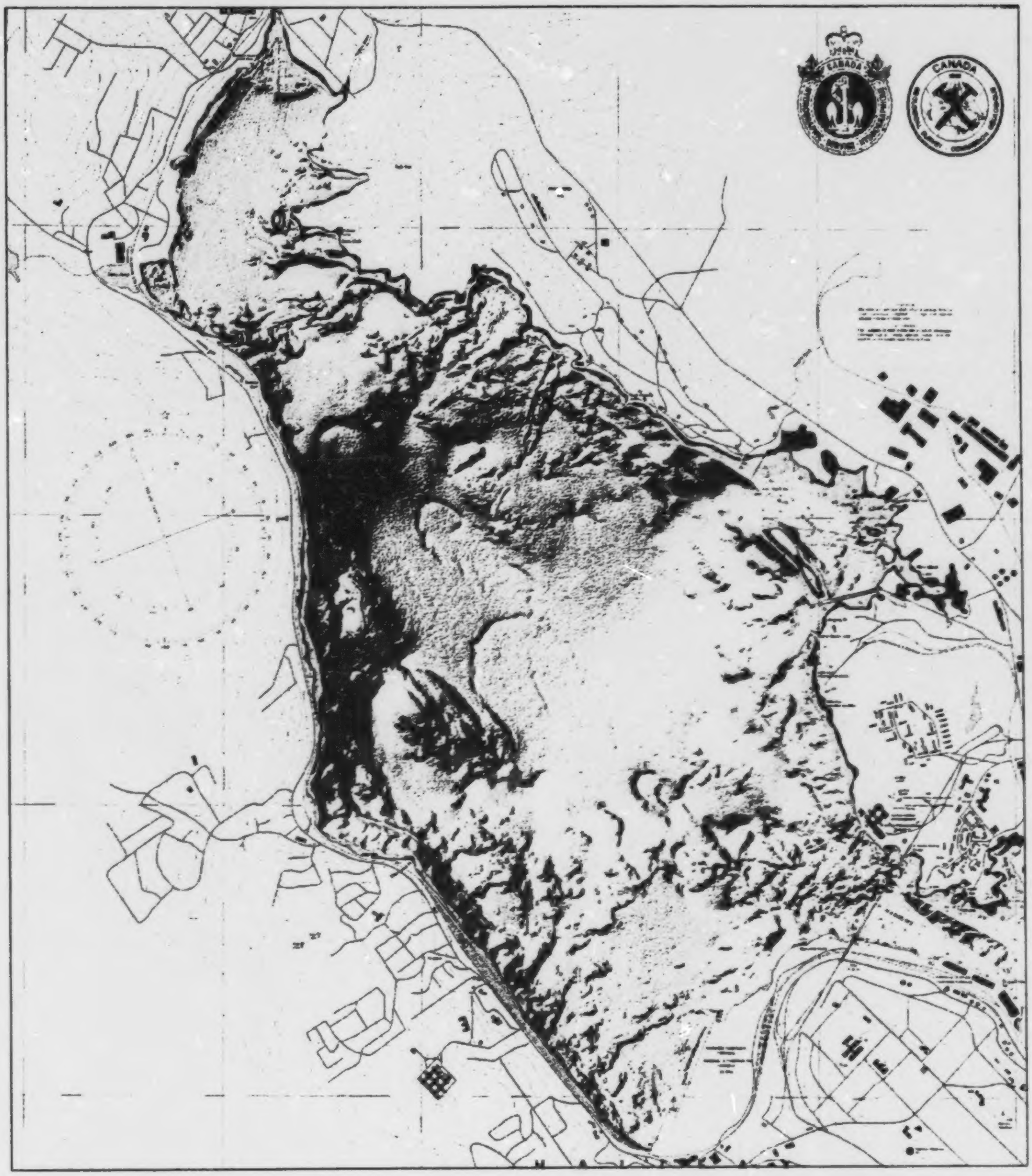


Figure 5: A shaded-relief, black and white muitibeam bathymetric image of Bedford Basin (Fader et al., 2000b). Prominent features include boulder berms ringing the basin at 23m water depth, anchor marks, shipwrecks, subsidence depressions in deep water, and areas of bedrock outcrop. A benthic habitat assessment sampling program can be based on this information and other interpreted maos of seabed character.

The Fishes of Halifax Harbour and its Approaches

Andrew Hebda and John Gilhen

Halifax Harbour and its Bedford Basin is one of a series of estuaries found along the Atlantic coast of Nova Scotia. It is classified in Nova Scotia theme region 800 (Davis and Browne 1997). Each estuary is different in size, physical structure and biological diversity. The one feature they all have in common is exceptionally productive habitats (we recognize an estuary in the broadest terms of the definition). These complex habitats support a diversity of fishes.

Undisturbed estuaries serve many important functions for fish. They are:

- home for a variety of euryhaline fishes;
- home for a variety of small marine fishes;
- nursery areas for a number of larger marine fishes;
- holding tanks for adult anadromous fishes;
- acclimation tanks for juvenile anadromous fishes;
- temporary summer refuge for visiting warm water fishes.

In addition, estuaries are frequent points of visitation for the scores of migrating species of fish, marine mammals, sea-turtles and birds found in the Western Atlantic. Unlike most of these estuaries, the Halifax Harbour is characterized by an advanced state of urbanization with resulting major changes to the surrounding watershed and shorelines.

Most resident fish in any estuary are associated with interfaces/substrates, most notably with vegetation such as attached macrophytes (aquatic plants). These habitats offer a complex array of features ranging from food, temperature and energy amelioration, to cover and protection. In addition, the dynamic interaction of freshwater with seawater results in an ecosystem of high productivity when compared to the associated (freshwater) watersheds and adjacent open ocean areas.

Prior to European settlement, some 400 years ago, the Sackville River and a number of smaller streams (notably Wrights Brook, Parker Brook and Kearney Run) flowed, unimpeded by anthropogenic structures, down pristine slopes. This river and these streams flowed into Bedford Basin, nourishing a series of estuarine coves on both sides of the Basin, these productive habitats supported a diversity of fishes. At these sites, temperature differences caused by freshwater incursion would also have increased the physical complexity of these habitats. In general, the more complex a habitat, the greater the resulting diversity of organisms, including fish.

Sites such as Mill Cove were reported to have had large beds of Zostera (marina). The flats now under the South end pier complex, including the container pier, received freshwater input from streams draining "The Commons" (west of the Citadel - Spring Garden - Public Gardens). As well, due to the prevailing circulation within this estuary, this area would have benefitted from nutrient transport outward along the south side of the harbour. It is thought that this may have, historically, been one of the more significant areas in the Estuary. In effect ,the estuary was a mosaic of habitats with some more suitable for continuous use by fish than others. Unfortunately there are few records of these habitats remaining so we can only speculate as to what was here before European settlement..

Changes in the structure of the Halifax Harbour watershed since the mid-19th century:

Many changes that we have seen in the watershed reflect a common pattern of urban development of a natural area. These include clearing of land, draining and in-filling of wetlands, channelization and containment of moving surface waters, and enrichment of nutrient regimes through release of entrained materials from existing ecosystems.

Comparison of early mapping of the associated watershed with contemporary surficial features indicates significant changes that have effects on these habitats. These include:

- Loss of 226 surface discharges of which 84 were in the Sackville River watershed;
- Loss of approximately 60 bodies of standing water or mapped wetlands;
- Inferred resultant loss of significant portions of riparian vegetation along remaining waters with concurrent changes in temperature and energy regimes of the remaining freshwaters;
- Introduction of exotic species of fish through plantings or unauthorized introductions or escapes.

We can infer that the filling of these shallow margins, along with the effective elimination of surficial discharge of "uncontaminated" fresh water from the Harbour, the Arm and the Basin has reduced the availability of many of the historic habitats. The reduction of these habitats has undoubtedly led to the impoverishment of the fish fauna.

A hint at the scope of the loss of these "horizontal" habitats, can be seen in the limited production characterized by vertical habitats. Shallow areas of high productivity with good light penetration and a relatively moderate energy regime are replaced by a relatively high energy vertical gradient on a sea wall or wharf structure.

Fundamentally, the fish fauna that we have in the Halifax Harbour estuary today reflects these changes to habitats, whether they are cultural enrichment of the Basin, loss of shallow habitats or loss of the array of freshwater inputs that defined the productivity of these waters.

Fish Present in the Estuary

A review of historical records provides some insight into what species have been found within the estuary. These species can be broken down into three categories: residents, migrants and strays or vagrants. The records noted below come from several sources including the Collections Database of the Nova Scotia Museum of Natural History, published reviews of Nova Scotian and Atlantic Ichthyofauna (Leim and Scott, 1966 , Gilhen, 1974, 1999, Scott and Scott, 1988 and Coad et al., 1995) , as well as archival literature of early fish reports. Taxonomy is as defined in Robins et al., (1991).

The summary (Table 1) provides a listing of these species with their residence status (resident, migrant, visitor) and date of record. Note is made if the species is a northern or southern visitor.

References

Coad, B.W., H. Waszczuk and I. Labignan, 1995, Encyclopedia of Canadian Fishes, Canadian Museum of Nature, Ottawa, 928 pages.

Davis, D.S. and S. Browne, 1997, Natural History of Nova Scotia, Vol 2, Theme Regions, Nova Scotia Museum, Halifax, 304 pages

Gilhen, J., 1974, The Fishes of Nova Scotia's Lakes and Streams, Nova Scotia Museum, Halifax, 49 pages.

Gilhen, J. 1999, Fishes of Nova Scotia: Species Recorded in the Accession Books of Harry Piers from 1899 to 1939, Nova Scotia Museum, Halifax, Curatorial Report Number 89, 153 pages.

Leim, A.H. and W.B. Scott, 1966, Fishes of the Atlantic Coast of Canada, Bulletin of the Fisheries Research Board of Canada, Ottawa, Number 155, 485 pages

Piers, H., 1899, Observations on a fish (Chylomycterus schoepfi) new to the fauna of Nova Scotia, Proceedings and Transactions of the Nova Scotia Institute of Science, Vol 10(1) pp 110-111.

Robins, C.R., Bailey, R.M., Bond, C.E., Brooker, J.R., Lachner, E. A., Lea, R.N. and W.B. Scott, 1991, Common and Scientific Names of Fishes from the United States and Canada, fifth edition, American Fisheries Society, Bethesda, Special Publication Number 20, 183 pages

Scott, W.B., and M.G. Scott, 1988, Atlantic Fishes of Canada, Canadian Bulletin of Fisheries and Aquatic Sciences Number 219, 731 pages

Table 1: Marine fishes recorded from Halifax Harbour, Bedford Basin and immediate environs from the collections and records of the Nova Scotia Museum of Natural History

Petromyzontidae - Lampreys	Sea Lamprey, *Petromyzon marinus*	Present within watershed		R
Alopiidae - Thresher Sharks	Thresher Shark, *Alopias vulpinus*	1984	off Cow Bay	SV
Lamnidae - Mackerel Sharks	Porbeagle, *Lamna nasus*	1924	3 mi SE of Devil's Island	M
	White Shark, *Carcharodon carcharias*	Present in estuarine area		M
Carcharhinidae - Requiem Sharks	Blue Shark, *Prionace glauca*	1909	off mouth of harbour	M
		1920	3 mi off Chebucto Head	
		1920	4 mi SE of Chebucto Head	
		1934	East of entrance to harbour	
Sphyrnidae - Hammerhead Sharks	Smooth Hammerhead, *Sphyrna zygaena*	1932	Halifax Harbour (S&S)	SV
		1938	Sambro Island (S&S)	
Squalidae- Dogfish Sharks	Dogfish, *Squalus acanthias*	1902	Northwest Arm	M
		1921	off Halifax Harbour	
Torpedinidae - Electric Rays	Atlantic Torpedo, *Torpedo nobliana*	1971	Halifax Harbour	M
Rajidae - Skates	Barndoor Skate, *Raja laevis*	Present in estuarine area		M
Elopidae - Tarpons	Tarpon, *Megalops atlanticus*	Present in estuarine area		SV
Anguillidae - Eels	American Eel, *Anguilla rostrata*	1912	North West Arm	R
Muraenidae - Morays	Green Moray Eel, *Gymnothorax funebris*	1952	Eastern Passage	SV
Clupeidae - Herrings	Atlantic Herring, *Clupea harengus*	Commercial species within area		M
	Alewife, *Alosa pseudoharengus*	1877	off Halifax	M

	American Shad, *Alosa sapidissima*	Present in estuarine area		M
	Atlantic Menhaden, *Brevoortia tyrannus*	Present in estuarine area		SV
	Round Herring, *Etrumeus teres*	Present in estuarine area		SV
Osmeridae - Smelts	Capelin, *Mallotus villosus*	Present in estuarine area		M
	Rainbow Smelt, *Osmerus mordax*	1900	near Halifax	R
Salmonidae - Trouts	Atlantic Salmon, *Salmo salar*	Present within watershed		R/M
	Brook Trout, *Salvelinus fontinalis*	Present within watershed		R
Gadidae- Codfishes	Fourbeard Rockling, *Enchelyopus cimbrius*	1877	off Halifax	R
		1901	North West Arm	
	Atlantic Cod, *Gadus morhua*	1911	near Halifax	R
		1996	North West Arm	
	Haddock, *Melanogrammus aeglefinus*	Present in estuarine area		R
	Atlantic Tomcod, *Microgadus tomcod*	Present in estuarine area		R
	Pollock, *Pollachius virens*	1996	North West Arm	R
	Silver Hake, *Merluccius bilinearis*	1877	off Halifax	M
		1909	North West Arm	
	Spotted Hake, *Urophycis regius*	*ca* 1836	Halifax Harbour (S&S)	SV
Lophiidae - Goosefishes	Goosefish, *Lophius americanus*	1871	off Halifax	R
Ceratiidae - Seadevils	Deepsea Angler, *Ceratias holboelli*	1991	off Halifax	V
Exocoetidae - Flyingfishes	Spotfin Flyingfish, *Cypselurus furcatus*	Present in estuarine area		SV
	Atlantic Flyingfish, *Cypselurus melanurus*	1970	Prospect	SV
	Blackwing Flyingfish, *Hirundichthys rondeleti*	1970	Prospect	SV
Scomberesocidae - Sauries	Atlantic Saury, *Scomberesox saurus*	1968	Pier 9	M
Cyprinodontidae - Killifish	Banded Killifish, *Fundulus diaphanus*	Present in estuarine area		R

	Mummichog, *Fundulus heteroclitus*	Present in estuarine area		R
Atherinidae - Silversides	Atlantic Silverside, *Menidia menidia*	1877	off Halifax	R
Zeidae - Dories	Buckler Dory, *Zenopsis conchifera*	Present in estuarine area		SV
Gasterosteidae - Sticklebacks	Fourspine Stickleback, *Apeltes quadracus*	1877	off Halifax	R
		1913	North West Arm	
	Threespine Stickleback, *Gasterosteus aculeatus*	1877	off Halifax	R
	Blackspotted Stickleback, *Gasterosteus wheatlandi*	Present in estuarine area		R
	Ninespine Stickleback, *Pungitius pungitius*	Present in estuarine area		R
Fistulariidae - Cornetfishes	Bluespotted Cornetfish, *Fistularia tabacaria*	1863	Halifax Harbour (S&S)	SV
Syngnathidae - Pipefishes	Lined Seahorse, *Hippocampus erectus*	1934	Halifax Harbour (L&S)	SV
	Northern Pipefish, *Syngnathus fuscus*	1901	Cow Bay	R
		1909	Melville Island NWA	
		1910	Mill Cove BB	
		1913	North West Arm	
		1918	Jollimore NWA	
		1931	Long Cove BB	
		1931	Halifax Harbour	
Dactylopteridae - Flying Gurnards	Flying Gurnard, *Dactylopterus volitans*	Present in estuarine area		SV
Cottidae - Sculpins	Atlantic Sea Raven, *Hemitripterus americanus*	1921	North West Arm	R
	Grubby, *Myoxocephalus aeneus*	Present in estuarine area		R
	Longhorn Sculpin, *Myoxocephalus octodecemspinosus*	Present in estuarine area		R
	Shorthorn Sculpin, *Myoxocephalus scorpius*	1877	off Halifax	R

Agonidae - Poachers and Alligatorfish	Alligatorfish, *Aspidophoroides monopterygius*	1877	off Halifax	R
Cyclopteridae - Lumpfishes and Snailfishes				
	Sea Tadpole, *Careproctus reinhardi*	1877	off Chebucto Head (L&S)	R
	Lumpfish, *Cyclopterus lumpus*	1904	Halifax Harbour	R
		1923	Jollimore NWA	
	Atlantic Spiny Lumpsucker, *Eumicrotremus spinosus*	ND	off Halifax Harbour (L&S)	NV
	Atlantic Seasnail, *Liparis atlanticus*	Present in estuarine area		R
	Striped Seasnail, *Liparis liparis*	Present in estuarine area		R
Serranidae - Basses	Snowy Grouper, *Epinephelus niveatus*	1928	Eastern Passage (S&S)	SV
Percichthyidae - Temperate Basses	White Perch, *Morone americana*	1901	near Cow Bay	R
		1902	Cole Harbour	
	Striped Bass, *Morone saxatilis*	Present in estuarine area		R
Pomatomidae- Bluefishes	Bluefish, *Pomatomus saltatrix*	Present in estuarine area		SV
Echeneidae -Remoras	Sharksucker, *Echeneis naucrates*	1928	Herring Cove (S&S)	SV
	Spearfish Remora, *Remora brachyptera*	1950	harbour approaches (S&S)	SV
	Remora, *Remora remora*	1982	Prospect	SV
Carangidae - Jacks	Blue Runner, *Caranx crysos*	1934	Herring Cove(L&S)	SV
		1968	Prospect	
	Crevalle Jack, *Caranx hippos*	Present in estuarine area		SV
	Mackerel Scad, *Decapterus macarellus*	1928	Lawlor's Island (S&S)	SV
	Redtail Scad, *Decapterus tabl*	Present in estuarine area		SV
	Pilotfish, *Naucrates ductor*	1885	Halifax Harbour	SV
	Wreckfish, *Polyprion americanus*	Present in estuarine area		SV
	Atlantic Moonfish, *Selene setapinnis*	1929	Eastern Passage (L&S)	SV

	Banded Rudderfish, *Seriola zonata*	1968	Bedford Basin	SV
		1970	Pennant	
		1885	off Devils Island	
		1968	off Pier 34	
Coryphaenidae - Dolphins	Dolphin, *Coryphaena hippurus*	1901	Bedford Cove BB	SV
Mullidae -Goatfishes	Red Goatfish, *Mullus auratus*	1928	Eastern Passage (S&S)	SV
Chaetodontidae - Butterflyfishes	Spotfin Butterflyfish, *Chaetodon ocellatus*	Present in estuarine area		SV
Mugilidae - Mullets	White Mullet, *Mugil carema*	Present in estuarine area		SV
Sphyraenidae - Barracudas	Northern Sennet, *Sphyraena borealis*	1928	Halifax Harbour	SV
Labridae - Wrasses	Cunner, *Tautogolabrus adspersus*	1877	off Halifax	R
Zoarcidae - Eelpouts	Wolf Eelpout, *Lycenchelys verrilli*	Present in estuarine area		NV
	Ocean Pout, *Macrozoarces americanus*	1877	off Halifax	R
Stichaeidae - Pricklebacks	Snake Blenny, *Lumpenus lumpretaeformis*	1973	Halifax Harbour	NV
	Arctic Shanny, *Stichaeus punctatus*	1966	North West Arm	NV
	Radiated Shanny, *Ulvaria subbifurcata*	1965	North West Arm	R
		1966	North West Arm	
Pholidae - Gunnels	Rock Gunnel, *Pholis gunnellus*	Present in estuarine area		R
Anarhichadidae - Wolffishes	Atlantic Wolffish, *Anarhichas lupus*	Present in estuarine area		R
Scombridae - Mackerels	Skipjack Tuna, *Katsuwonus pelamis*	1972	Eastern Passage	SV
	Atlantic Bonito, *Sarda sarda*	1885	Halifax Harbour	SV
	Chub Mackerel, *Scomber japonicus*	1931	Herring Cove (S&S)	SV
	Atlantic Mackerel, *Scomber scombrus*	Commercial species within area		R

	Albacore, *Thunnus alalunga*	1922	off Devil's Island	SV
	Bluefin Tuna, *Thunnus thynnus*	Present in estuarine area		M
Xiphiidae - Swordfishes	Swordfish, *Xiphias gladius*	Present in estuarine area		M
Stromateidae - Butterfishes	American Barrelfish, *Hyerglyphes perciformis*	1927	Halifax Harbour	SV
		1934	Halifax Harbour	
	Butterfish, *Peprilus triacanthus*	Present in estuarine area		M
Pleuronectidae - Righteye Flounders	American Plaice, *Hippoglossoides platessoides*	1973	Halifax Harbour	NR
	Atlantic Halibut, *Hippoglossus hippoglossus*	1973	Halifax Harbour	R
	Winter Flounder, *Pleuronectes americanus*	1901	near Cow Bay	R
		1910	Eastern Passage	
	Yellowtail Flounder, *Pleuronectes ferrugineus*	1922	off Halifax Harbour	R
	Smooth Flounder, *Pleuronectes putnami*	1920	near Halifax	R
Balistidae - Leatherjackets	Orange Filefish, *Aluterus schoepfi*	1938	Herring Cove (S&S)	SV
	Planehead Filefish, *Monocanthus hispidus*	1928	Halifax Harbour (L&S)	SV
	Gray Triggerfish, *Balistes capriscus*	1910	Halifax Harbour	SV
		1935	Eastern Passage	
		1937	Halifax Harbour (L&S)	
		1950	Halifax Harbour (L&S)	
Tetraodontidae - Puffers	Striped Burrfish, *Chilomycterus schoepfi*	ca1896	Sambro (Piers 1899)	SV
Molidae - Ocean Sunfishes	Ocean Sunfish, *Mola mola*	1873	Halifax Harbour	M
		1950	harbour approaches (L&S)	

Species summary

103 species in 51 families
33 species noted as "present in estuarine area"
3 species reported as "present within watershed" and
2 species reported as "commercial species in area"

Collection date denotes when the specimen was taken.

Species may be year-round residents (R), occasional northern visitors - at the south end of their normal range, (NV) - occasional southern visitors (SV) at the northern end of their normal range, or Migrants (M). Migrants includes diadromous fish as well as regularly occurring species .

Species noted as present in estuarine area have been reported from adjacent estuaries and are probably present within the study area.
Species noted as present in watershed are found in freshwaters, but are anadromous, thus will pass through the study area..
Commercial species in area are those for which there is a commercial harvest in the study area.

Benthic Fauna of Halifax Harbour

Susan Belford

Introduction

Much like the heteregenous and patchy nature of the marine benthos, biological surveys of Halifax Harbour vary considerably and include both qualitative and quantitative survey methods. Studies have been undertaken harbour-wide and/or in project specific locations. Most biological surveys have been conducted by Fisheries and Oceans research scientists or by consulting scientists working on specific projects. The latter surveys, while not typically available in the primary literature are generally accessible as they tend to be conducted under the public environmental assessment process. The purpose of many of the various surveys has been to evaluate the effect of sewage discharge on the marine benthos. This paper presents the findings of the larger projects which encompass several areas of the harbour.

Benthic Studies and Methodologies

One of the earliest studies conducted in Halifax Harbour was a quantitative grab sampling in Bedford Basin conducted over the Winter and Spring in 1970 (Platt et al. 1970). Seven sampling stations were established throughout Bedford Basin (Figure 1) in water depths ranging from <10 m to 70 m (Figure 1). A Van Veen grab sampler was used to collect sediment. The number of samples ranged from 3-10 grabs per station. Macrofauna >0.5 mm in size were recorded.

Between 1986 and 1988 an extensive grab sampling survey was undertaken by Hargrave and Buckley (1989) in a study to characterise the geochemistry of harbour sediments. Opportunistically, photographs of the sediment surfaces were taken of 122 of the 244 grabs and the species observed were described.

In the Fall of 1987 a qualitative underwater still camera survey was conducted by Hargrave et al. (1989) of four transects in the vicinity of Herring Cove (Tribune Head to Ferguson Cove) (Figure 1). Twenty sites in total were assessed: Tribune Head – 8 sites; Herring Cove – 5 sites; Sandwich Point – 3 sites; and Fergusons Cove – 4 sites. The camera was bounced over the seafloor for a 2 – 5 minute period, the weighted bottom trigger releasing the shutter upon contact with the seafloor. From each photograph, the macrophyte cover, sediment texture and invertebrates >2 cm were recorded.

In the Summer of 1989, 13 locations were sampled from Bedford Basin to McNabs Island. The infaunal community in the basin had low diversity with a high number of polychaete species similar to the findings from the 1970 study, as was the presence of *Cossura longicirrata*. Several locations in the harbour had low diversity benthic communities.

In the Summer of 1991, Halifax Harbour Cleanup Inc. completed an environmental survey of a proposed sewage treatment facility located on Ives Knoll and Ives Cove, north of McNab's Island (JWEL 1991, 1992). Thirteen Van Veen grab sampling stations were established in the project study area. Triplicate grabs (0.1 m^2) were collected at each station and sieved on 0.5 mm mesh.

Macrobenthic species were identified to species. In addition to the grab sampling program, a diving survey was included within Ives Cove of McNab's Island to record pre-construction habitat quality and benthic animal densities within 0.25 m^2 quadrats. The diving transects were 100 m long. An intertidal survey around Georges Island was also conducted

In September 1999, another field survey was launched to collect baseline conditions on behalf of the Halifax Regional Municipality's proposed sewage treatment project (JWEL 2001). The sampling program entailed the collection of sediment chemistry data and quantitative observations of surficial sediments at four outfall locations: Halifax North (near the casino), Georges Island, Woodside and Hospital Point (Figure 1). In anticipation of environmental assessment requirements for construction and operation of a proposed container ship terminal in Bedford Basin (Rockingham), the Halifax Port Corporation commenced the collection of baseline environmental data (JWEL, nd). One of the component studies was the evaluation of marine benthos and habitat that would be lost from infilling to accommodate construction of the terminal.

The marine survey program entailed establishing four long transects parallel to shore over the entire length of the proposed terminal. Seven stations were selected along each transect, approximately 100 m apart for a total of 68 survey stations. At each station a diver descended a weighted line and videotaped the seafloor within a 15 m radius.

Sublittoral Benthic Fauna Distribution

The benthic community assemblage is dictated, in large part, by the quality and quantity of benthic substrate, a significant component of marine habitat. The bottom topography and sediment composition is variable throughout the harbour. Moving down the littoral and sublittoral zones there appear to be four main types of habitats: 1) gravel/cobble interspersed with silty sand around the perimeter of the harbour and in isolated patches, 2) mud throughout Bedford Basin, the inner harbour and part of the middle harbour, 3) sand in the middle and outer harbour areas and 4) bedrock outcropping along the western shore and outer harbour.

The gravel/cobble shallow water substrates support a diverse epifauna community including small gastropods (*Littorina* sp. *Lunatia, Buccinum, Acmaea*), bryozoans sea anemones, sea urchin, starfish, blue mussels, rock crab, Jonah crab, hermit crab, lobster, sea scallops, cunner (JWEL 1999, Hargrave et al. 1989, Elner and Hamet 1984). Algal species observed included *Chondrus crispus, Fucus vesiculosus, Laminaria* spp., *Desmarestia aculeata, Corallina, Lithothamnium, Porphyra linearis, Ascophyllum nodosum, Agarum cribosum* and *Ulva lactuca*.

Areas subject to significant organic loading such as at Rockingham near the sewer outfall have soft, black, sulphide–rich sediments with a thin oxidized organic layer. Benthic surveys found polychaetes, white bacterial mat (eg. *Beggiatoa* sp.) and no epifaunal community. Similar findings were noted inside Drake Passage in the Eastern Passage area. Both of these areas, and elsewhere in the harbour, may not receive adequate flushing and the accumulation of organic matter (eg. seaweed) results in eutrophic conditions.

The seafloor in the Bedford Basin and inner harbour regions consist predominantly of muddy (silt and clay) sediments, typical in estuarine ecosystems.. This type of sublittoral habitat is homogeneous, unvegetated and without large topographic feature diversity. Polychaetes are the most numerous animals within these areas. Peer et al. (1970) recorded *Spiochaetoperus, Nereimyra* and *Edwardsia* (burrowing anemone) as the most abundant macroinfauna species. Other animals include Nemerteans, unspecified bivalves, gastropods, cumaceans (a small burrowing crustacean), starfish, brittle stars and sea cucumbers. The number of organisms present ranged from 2-16 species per 0.1 m^2 with a mean biomass of 50 g/m^2. Hargrave et al. (1989) compared species richness and biomass with St. Margarets Bay (20-30 species/m^2 and 26-300 g/m2) and Georges Bay (69-143 g/m^2). The composition of the benthic community at one station near the Mill Cove sewage treatment plant suggests an enrichment effect, as five more taxa observed were not present at any other sampling stations.

The 1991 Halifax Harbour benthic study in the area north of McNabs Island found 14-66 species per 0.1 m^2 with the dominant polychaete species Capitellidae, *Cossura longocirrata, Cerastoderma pinnulatum, Pholoe minuta* and *Laonice* sp. This finding is consistent with abundant *Cossura longicirrata* found by Peer at al. (1989 survey). The mean biomass was 13 g/m^2. This value is lower than for the Bedford Basin. The difference in species dominance between the 1970 and later studies may be a function of taxonomic skill, currents, sediment grain size, water depth or change in benthic community due to organic enrichment. Supporting information is not provided in the earlier studies for comparison.

The sediments south of Georges Island and near Woodside are described as a loose and fluid mud. Very few epibenthic organisms were observed over 200 m of transect (JWEL 1999, 2001). Polychaete fan worms, rock crab, starfish, sea anemone on litter and decomposing seaweed were the only animals and plants recorded. In the absence of hard substrate for colonising epilithic organisms, the abundant debris provides that feature. Typical debris items throughout the harbour consist of tires, timber, bottles, cans, barrels, waste metal, broken lobster traps, paper and plastics, and the occasional shipwreck.

Surveys of the sand substrate of the outer harbour area found a diverse epibenthic community consisting of brittle stars, scallops, sea urchins, cockles, quahaugs, rock crab, horse mussels, starfish, hermit crabs, and sculpins. The wave ripples observed in these areas are indicative of sediment transport resulting from wave action. The middle and outer harbour areas are exposed to the predominant south and southwest wind directions and storms.

The shoreline from about Purcells Cove and seaward is characterised by steep bedrock slopes. This feature continues to the nearshore bottom where the substrate grades into a mix of large boulders and exposed bedrock interspersed with coarse gravel. The stable and hard substrates are densely covered by a variety of seaweeds, typically brown and red species. Species that comprise the kelp (*Laminaria, Alaria*) form a canopy layer. The multiple layers of algae also provides habitat for small epiphytic plants and animals.

The multi-dimensional surfaces in the rocky subtidal habitat of these areas support the most diverse species communities. Many animals found in these areas are colonial encrusting species. The dominant species include sponges, tunicates, bryozoans, anemones, coralline algae and hydroids (Peer et al. 1989, JWEL). Other marine animals found here are similar to those observed in the gravel/cobble habitats including lobster, crabs, sea urchins, starfish, amphipods, small gastropods (*Littorina, Lunatia*) and a variety of demersal fish.

Summary

The harbour habitats reflect conditions typically found in estuaries with rocky shorelines and soft muddy depositional areas. The sandy areas of the outer harbour reflect the exposure to wind and wave action. Peer et al. (1989) interpreted a low species diversity as an indicator of environmental stress. The observed anoxic conditions were considered to result from pollution and/or limited water exchange in the harbour inlet. The middle and outer harbour areas appear to support a benthic environment typical for coastal Nova Scotian waters with no apparent evidence to suggest organic enrichment from sewage. Areas within close proximity to sewage outfalls in the inner harbour and Bedford Basin show a measureable change in benthic communities from sewage discharge.

References

Elner, R.W. and S.L. Hamet. 1984. The effects of ocean dumping of dredge spoils onto juvenile lobster habitat: a field evaluation. Can. Tech. Rep. Fish. Aquat. Sci. 1247:10 pp.

Hargrave, B.T., D. Peer and H. Wiele. 1989. Benthic biological observations. In: Investigations of Marine Environmental Quality in Halifax Harbour. Can. Tech. Rep. Fish. Aquat. Sci. 1693:9pp.

D. E. Buckley and B.T. Hargrave. 1989. Geochemical characteristics of surface sediments. In: Investigation of marine environmental quality in Halifax Harbour. Can. Tech. Rep. Fish. Aquat. Sci. 1693:9pp.

Jacques Whitford Environment Limited. 1991. Halifax-Dartmouth Metropolitan Sewage Treatment Facility. Component Study Report. Marine Biological Environment. Report to Halifax Harbour Cleanup Inc. 25 pp + 8 appendicies.

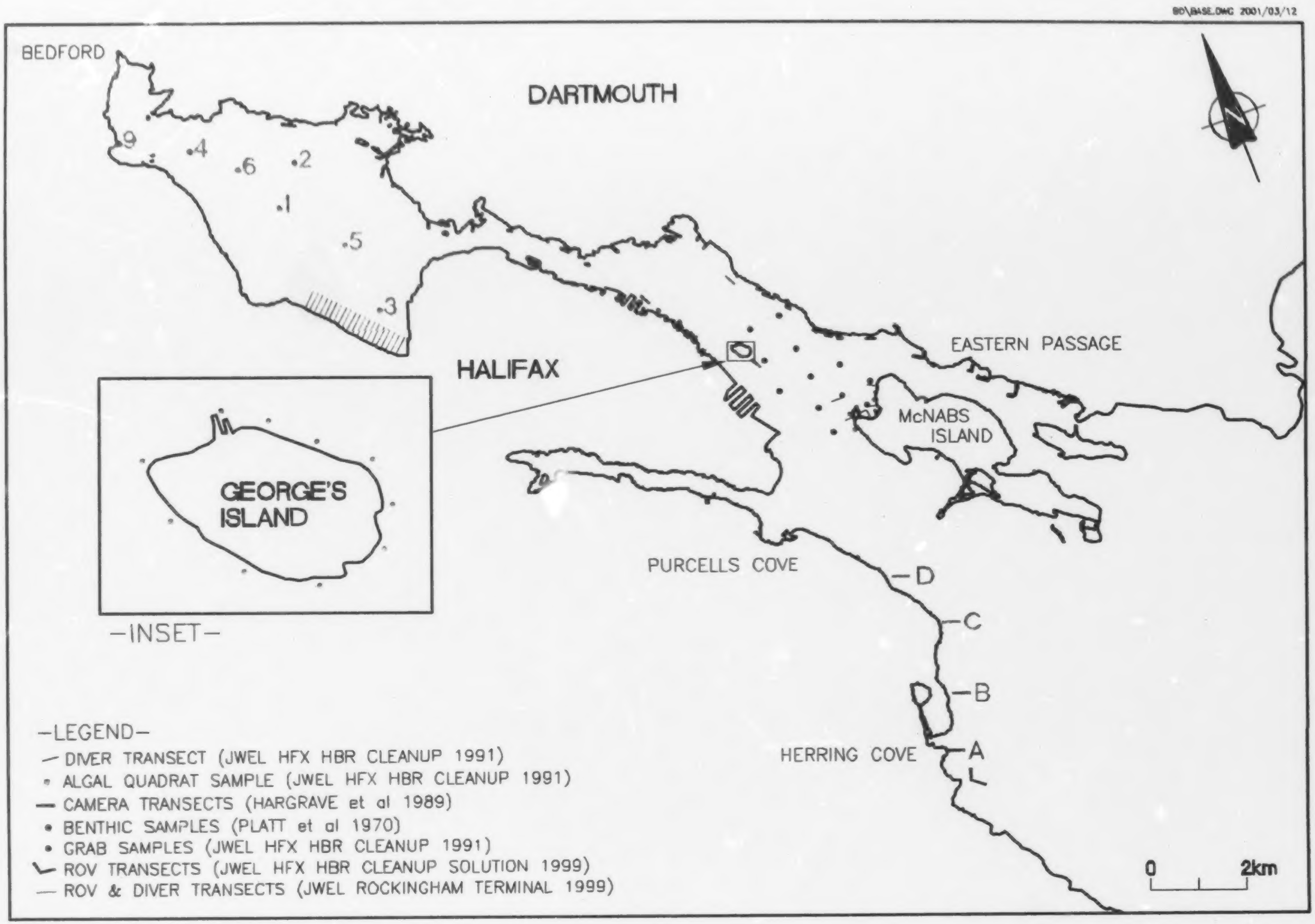
Jacques Whitford Environment Limited. 1992. Environmental Assessment Report. Volume I Project Description and Existing Conditions. 288 pp + figures, tables and appendix.

Jacques Whitford Environment Limited. 1999. Marine Benthic Habitat and Sediment Characterisation at Each Diffuser Site. Report to Halifax Regional Municipality.

Jacques Whitford Environment Limited. 2001. Halifax Harbour Solutions Project Environmental Screening. Draft Report to Halifax Regional Municipality.

Peer, D.L., A. Adamson, and B.T. Hargrave. 1989. Infaunal macrobenthos of Halifax Inlet. In: Proceedings of the First Halifax Inlet Research Workshop, Bedford Institute of Oceanography. Dartmouth.

Platt, T. R.J. Conover, R. Loucks, K.H. Mann, D.L. Peer, A. Prakash and D.D. Sameoto. 1970. Study of a eutrophicated marine basin. FAO Technical Conf. on Marine Pollution and its effects on Living Resources and Fishing, Rome, Italy.


BD\BASE.DWG 2001/03/12
BEDFORD
DARTMOUTH
9
4
6
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HALIFAX
EASTERN PASSAGE
McNABS ISLAND
GEORGE'S ISLAND
-INSET-
PURCELLS COVE
D
C
B
HERRING COVE
A
-LEGEND-
DIVER TRANSECT (JWEL HFX HBR CLEANUP 1991)
ALGAL QUADRAT SAMPLE (JWEL HFX HBR CLEANUP 1991)
CAMERA TRANSECTS (HARGRAVE et al 1989)
BENTHIC SAMPLES (PLATT et al 1970)
GRAB SAMPLES (JWEL HFX HBR CLEANUP 1991)
ROV TRANSECTS (JWEL HFX HBR CLEANUP SOLUTION 1999)
ROV & DIVER TRANSECTS (JWEL ROCKINGHAM TERMINAL 1999)
0
2km

The Waterbirds of Halifax Harbour.

Dr. A. R. Lock

Halifax Harbour has some 135 km of shoreline which is the habitat of a numerous and diverse water bird fauna. The birds that one sees in and around the harbour are usually quite large, and they are at or near the top of the coastal marine food chain. Their habitat is the air-sea interface above shallow coastal water and because of their size and habitat choice they are usually easy to monitor and some may serve as an indicator of environmental health.

Perhaps the most common seabirds in a coastal urban environment are gulls. These are large birds with a noted behavioral flexibility, a well known ability to thrive in environments altered by human activity. They can augment natural foraging in the inter-tidal zone by exploiting sewer outlets, waste tips and human picnic discards for food, and when natural islands become unavailable for undisturbed nesting, they will find artificial "islands" on the roofs of high-rise buildings or on the tops of oil tanks at oil refineries. But while these birds thrive in human company, most other species of water birds are disadvantaged by environmental changes, being driven from their usual habitats by human alterations and activities. The coastline of the central Harbour is now completely artificial and virtually devoid of water birds other than gulls and a few black ducks. But Bedford Basin and the outer harbour are less altered and still maintain some degree of the original diversity of water birds native to this region.

The water bird fauna is constantly changing, having fewest species present in summertime when most species have withdrawn to breed. During spring and fall migrations the species composition is constantly changing as birds move through the area. It is only during the winter months that a stable population of birds establishes itself.

If we are to look to water bird populations as indicators of more or less unaltered coastal habitat we must look at the stable wintering populations. The Canadian Wildlife Service has, for several decades, monitored the abundance of coastal water birds by low-level aerial surveys carried out from a slow-flying high-winged aircraft. Results of such surveys are compiled by census blocks, which are areas of coastline of varying length, but which usually contain a consistent habitat type. The census blocks for the area around Halifax Harbour are shown in Figure 1. Thus, Halifax Harbour itself is divided up into two areas: Bedford Basin and the outer harbour.

Table 1 consolidates the results of aerial surveys of coastal waterfowl carried out over the last 25 years in the winter months between December and March, at which time coastal bird populations are most stable. To allow comparison with St Margaret's Bay, a less industrially developed embayment, I have collected winter data from survey blocks 188 at the western mouth of St. Margaret's Bay, to 197 at the mouth of Halifax Harbour. This table reports numbers of dabbling ducks; birds such as Black Ducks which dabble or feed in shallow waters, Bay Ducks like Mergansers which pursue fish by pursuit diving and Sea Ducks such as Eiders and Scoters which dive in deeper waters to recover mussels.

In Table 1 three areas are examined separately;

St. Margaret's Bay, the exposed shore from Peggy's Cove to Chebucto Head, and Halifax Harbour itself. It is apparent that in each area seaducks are predominant. Dabblers, which are mainly Black Ducks are relatively rare except in the outer harbour of Halifax. Overall, bay ducks are even less abundant than dabblers, with Red-breasted Mergansers being the most abundant of this group. Sea ducks, birds which gather in flocks over shallow rocky shorelines with abundant mussel habitat make up the great majority of the wintering waterfowl. Common Eiders and two or three species of Scoters make up this group.

The densities of ducks on the coast are highly variable. Within St. Margaret's Bay, where seaduck habitat is less abundant, there are very few ducks counted - an average of just 0.5 ducks per km of coastline. Along the exposed coast from Peggy's Cove to Chebucto Head seaducks naturally predominate and the mean number of ducks per km increases by a factor of three to 1.5 per km. Within Bedford Basin the waterfowl density approximates that within St. Margaret's Bay with which it shares similar habitat. However, in the outer Harbour of Halifax, waterfowl are extremely abundant with close to ten thousand ducks in winter residence, a mean density of close to 10 birds per km.

At present the most immediate threat to harbour birds is that posed by careless management of oil, a commodity which is used in, and transported through, all industrial harbours. In winter time a bird's plumage is an effective insulation, allowing it to live and dive in freezing waters with no harm. Oil, when released into the sea, concentrates at the air-sea interface, the habitat of water birds. If a bird comes into contact with oil, oil will matt its feathers allowing frigid water to penetrate to the skin, and the afflicted bird dies of hypothermia. At the first workshop "Preserving the Environment of Halifax Harbour" in 2000, Roger Percy of the Environmental Protection Branch of Environment Canada summarized data on oil spills into Halifax Harbour. Between 1994 and 1999 there was a consistent decline in number of spills reported, from around 140 to about 80 per year. While this negative trajectory is encouraging, oil spills into the Harbour still occur with a disturbing frequency. Spills which are confined to the industrial heart of the harbour do the least harm, but any spills in the outer harbour have the potential to do great harm. Unfortunately the oil refineries in Halifax are located in the richest water bird habitat of the outer harbour and careless operations at these sites pose a persistent threat to preservation of the bird populations that use the harbour mouth.

The diversity of the waterbird population is not well shown by the CWS aerial surveys. Rare species tend not to be counted accurately and some quite cryptic birds may not be seen at all. Some indication of the richness of our harbour bird fauna is given by Christmas Bird Counts which are annual counts made by amateurs across North America over the Christmas period. Table 2 presents one such count made on MacNab's Island in 1997. The species and numbers observed are not atypical, on another count some half dozen other species might be recognized. This table also presents a day's casual observations made from a house on Purcell's Cove. These observations show that a remarkably rich seabird community winters in the outer reaches of Halifax Harbour. But this is a resource that is vulnerable and can be easily lost. That our citizens value this resource is shown by the large numbers of people who flock to the outer harbour birding on weekends, and by the high value of real estate at the water's edge where this remarkable population can be observed. This community of waterbirds will not survive if we ignore it. ***Our plans for harbour management and development must be directed to preservation of the habitat of these birds. If their habitat is destroyed the birds will disappear and all citizens of Halifax will be the poorer.***

TABLE 1. **Numbers of dabbling, bay and sea ducks counted on Canadian Wildlife Service aerial surveys of the coastline from Blandford to Hartlen Point, December to March.**

SAINT MARGARET'S BAY - BLANDFORD TO PEGGY'S COVE

BLOCK NO.	TOTAL DABB.	TOTAL BAY	TOTAL SEA	TOTAL DUCKS	No. SURVEYS	No. DUCKS /SURVEY	COAST Km.	DENSITY DUCKS/KM.
188	33	22	1,648	1,703	15	113.5	32.35	3.5
189	0	36	213	249	8	31.1	14.4	2.2
190	0	303	2	305	5	61	64.02	1
191	0	62	0	62	5	12.4	70.33	0.2
192	7	3	1,148	1,158	14	82.7	38.31	2.2
TOTALS	40	426	3,011	3,477	47	74	148.75	0.5

PEGGY'S COVE TO CHEBUCTO HEAD

BLOCK NO.	TOTAL DABB.	TOTAL BAY	TOTAL SEA	TOTAL DUCKS	No. SURVEYS	No. DUCKS /SURVEY	COAST Km.	DENSITY DUCKS/KM.
193	6	85	1,809	1,900	8	237.5	109.19	2.2
194	7	23	1,083	1,113	8	139.1	113.38	1.2
195	61	36	2,474	2,571	8	321.4	64.53	5
196	0	17	10,893	10,910	8	1363.8	48.72	28
TOTALS	74	161	16,259	16,494	32	515.4	335.82	1.5

HALIFAX HARBOUR

BLOCK NO.	TOTAL DABB.	TOTAL BAY	TOTAL SEA	TOTAL DUCKS	No. SURVEYS	No. DUCKS /SURVEY	COAST Km.	DENSITY DUCKS/KM.
197	1,923	193	7,814	9,930	11	902.7	93.62	9.6
198	19	9	0	28	1	28	41.03	0.7
TOTALS	1,942	202	7,814	9,958	12	930.7	134.65	6.9

Table 2. Birds observed on the Christmas Bird Count (CBC), MacNab Island 1997 and casually March 9, 2001 at house in Purcell's C

CBC MacNab's 1997		Purcell's Cove	
Common Loon	2	Common Loon	1
Red-necked Grebe	2	Red-necked Grebe	3
Great BlueHeron	1	Pied-billed Grebe	1
Oldsquaw	35	Great Cormorant	1
Common Goldeneye	30	Oldsquaw	2
Bufflehead	13	Red-breasted Mergans	13
Greater Scaup	40	White-winged Scoter	7
Common Eider	306	Black Scoter	4
Red-breasted Merganser	41	Herring Gull	17
Black Duck	68	Iceland Gull	1
Gadwall	1	Great Black-backed gu	6
Herring Gull	88	Black Guillemot	3
Iceland Gull	17	Black Duck	8
Great Black-backed Gull	26	Harbour Seal	3
Ring-billed Gull	12	Mink	2

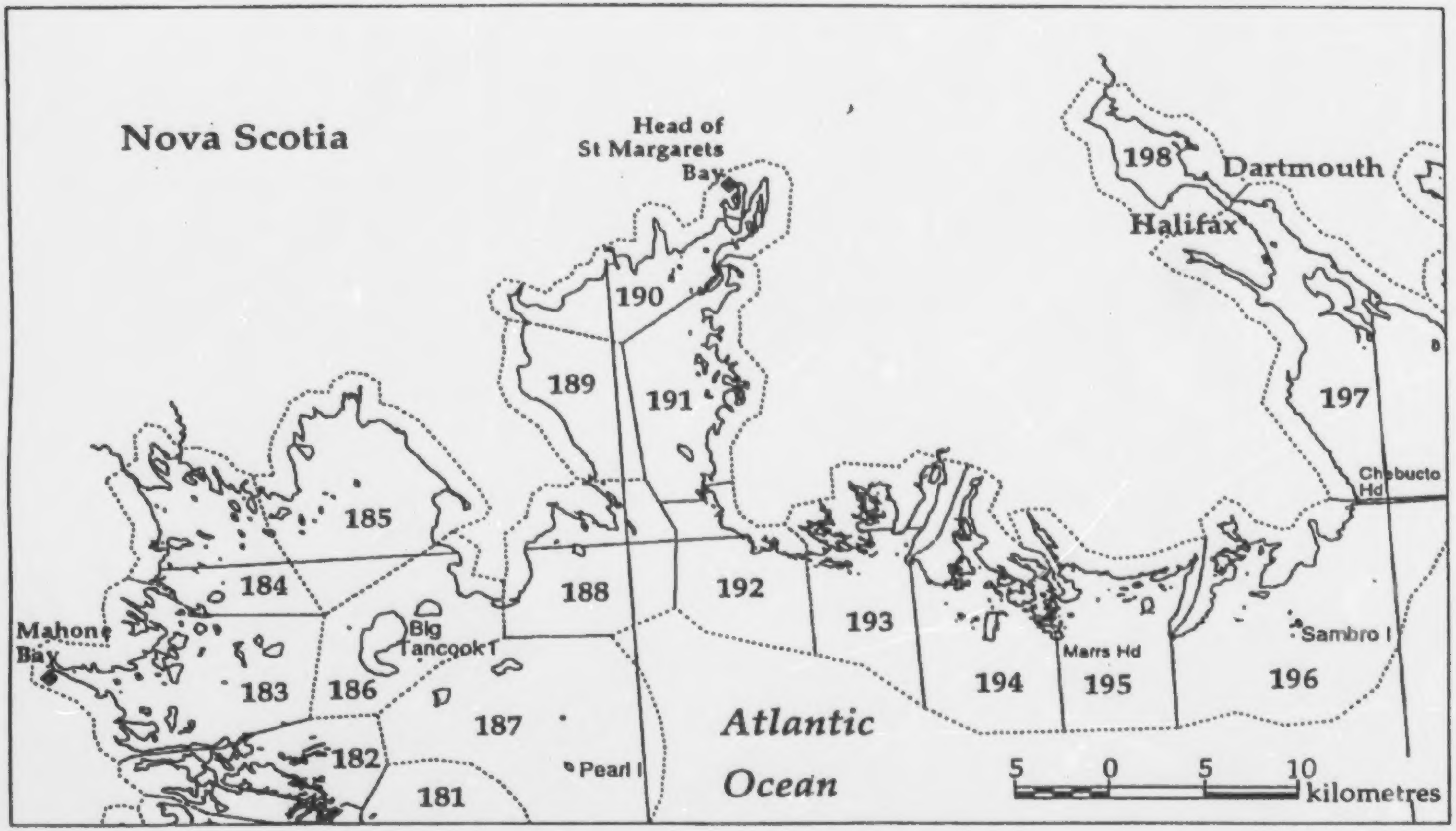


Figure 1: Coastal blocks used to compile Canadian Wildlife Service aerial survey data.

Questions and Answers
Workshop Introduction

Question:
Using the "no net loss principle", can an NGO apply for funding to develop a fishway to provide more fish into an area to compensate for lost habitat, even though habitat loss from a development project may not be in their specific area?

Jim Ross:
If a developer is working in an area and there will be in impact on habitat or fish stocks in that area, DFOP will generally try to apply compensation (provide funds to enhance habitat or stocks) in that particular area. If this is not possible DFO may look to compensate in an area further afield.

Question:
How retroactive is the Fisheries Act re-past habitat or fish stock disruption? That is, if some action has altered a stream years ago and destroyed or degraded fish habitat, could the Fisheries Act be used to require compensation?

Jim Ross:
The Act could not, in that case, be used to require compensation, but DFO could work independently with interest groups to enhance existing stream habitat today.

Question:
What exactly do you mean by the phrase "no net loss" of habitat?

Jim Ross:
If fish habitat is lost or altered by some development activity then, in most cases, compensation is required from the developer. This means that new fish production potential may be required through such things as stocking or creation of new habitat (opening new areas).

Question:
What is the priority for Halifax Harbour in terms of restoration of fish habitat as it relates to the Harbour as a fish feeding area?

Jim Ross:
It is not really up to DFO right now to decide this. Much of the alteration that has taken place in the Harbour has occurred over 100's of years and cannot now be altered by use of something like the Fisheries Act. It will be up to the Harbour stakeholders who want to influence the Habour habitat for their own benifit - for recreation, fishing, etc.

Question:
Sewage plant diffusers from the new sewage plants to be constructed are bound to cause some alteration in the ecological zones in the harbour. Other development projects could cause further problems. Would DFO take into consideration these possible changes?

Jim Ross:
We couldn't say specifically at this time, but DFO would definitely work with individuals and groups to look at potential impacts and manage them.

Question:
Is there a "rule of Thumb: regarding how applications for infilling are handled?

Jim Ross:
No, no really. At present each application is looked at on a case by case basis.

Question:
Who will hone the results of conversations and discussions that take place in this Workshop and the previous onelast year such that there will be some continuity between them and other Harbour initiatives. Is there a core group of members to do this?

Brian Nicholl's:
There is no core group to insure continuity. Possibly this is a recommendation that could come out of the Workshop.

Question:
What are we doing with respect to the environment of Halifax Harbour? Are we trying to maintain the status quo? This is unacceptable. Where should we be going regarding this issue?

Brian Nicholl's:
Hopefully the discussion over the next two days will address this issue. In my opinion the status quo is not acceptable and we have convened this Workshop and the previous one to try to make the Harbour a better place for it's biota and for the people living around the Harbour.

Question:
Four of the six recommendations from the last Workshop stated that HRM should take the lead role in the Harbour cleanup. Have they done so at this time? Can they be held accountable?

Brian Nicholl's:
We have taken 250 years to get the Harbour in the shape we now find it. Although accountability on everyones part is not yet established, we have to recognize we are working with a new process. It is encouraging that we continue to discuss and work towards Harbour cleanup, and it is equally important that we continue to establish a solid base from which to work.

Part 2

Spectrum of Harbour Activities

Major Development Projects of the Past

Alan Ruffman

** This paper was not available in time for publication with the Proceedings.

Cumulative Infilling Activities

Clarence Spencer

Introduction

Some 30 years ago I started my career here at BIO. I have on several occasions over the years made my way back and each time I am pleased to be here as I am today.

As we all know, Halifax has a history dating back more than 200 hundred years. In all that time the activity of infilling has gone on non stop to the present day. Much of the infilling activities of the past were undertaken in support of much needed commerce and the shipping industry and would be considered at the time to be justified. Infilling would have been done in the best interest and needs of the public. Our environmental conscience was not very well developed in those early days. Today things are different, we recognize the impacts of such activity on the aquatic environment and must rethink the value to society of this activity.

When I was asked to make a presentation at this workshop I was very pleased, for two reasons. First because of the topic, infilling, which is one of those topics that is very close to my environmental heart and second because of the audience assembled here today. I am aware of the knowledge and sensitivity many in this room would have towards the topic of infilling, and in particular infilling into Halifax Harbour. I feel sure that I will find someone in this audience who support my feelings on the practice of infilling. I would like to point out that the following comments are my personal opinions on the topic of infilling.

After pondering the subject for a while and trying to decide what direction I should take with this presentation, I came to the conclusion that I don't think I can add anything to this topic that most, if not all, in this room are not already aware. As a result I did not see what value there would be in discussing what is already well known.

Infilling is a simple activity but one that, in my mind has a significant consequence for the aquatic environment. In my opinion infilling degrades the quality of the aquatic environment, and reduces it's value in many ways.

With that in mind I have decided to take a different direction. Rather than focus all my time on Halifax Harbour with my presentation, I would like to spend time drawing your attention to a global perspective on infilling.

Infilling

Over the years I had the opportunity to observe first hand what infilling was all about. I conducted site inspections on numerous infilling projects around the Atlantic Region both from above and below the water line. I have seen the best and the worst of this activity. Some proponents of infill projects were very sensitive to the environment during the development of their project. They took care to ensure only quality fill was used and installed and maintained mitigating measures to help minimize impacts. Others had little interest in protecting the environment, and used whatever fill material was available, even if that material was of poor quality. Mitigation was a foreign word and was never applied to their activities.

On one occasion I observed a proponent using only manure as infill material. I have also witnessed large infill areas with only wood bark as the fill material or fine dredge spoils. Some of which find their way back to the water course through poorly designed and constructed containment facilities.

Boundaries

This topic of infilling has occupied my thoughts off and on for many years. I will admit up front I am not a proponent of infilling as a development strategy. I, like many others in this room live on a parcel of land e.g. a city lot which is bounded by property lines. All of my activities must be contained within those boundaries. To do otherwise could end up in the courts.

As they say fences make for good neighbors and one has to respect the rights of the owners of the adjacent lands. That is not only the law of the land, but it is also an unwritten law that is required in order to be a good neighbor.

Unfortunately, this law at times can break down. Some property owners with a watercourse as a boundary line don't respect that line or at the very least, consider it elastic. With a little money, a source of fill, and sometimes not much more reason than a whim, they expand their land holdings through infilling at the expense of public lands and the aquatic environment.

Ownership

No one in this room I am sure would appreciate coming home to their private property to find that it has been significantly and perhaps permanently altered by someone else without permission.

I consider all watercourses in this country as my property, mine, as a citizen of this province and of this country. Such lands are referred to as the Commons. As one of the owners of the Commons I question having that property permanently altered through infilling without just cause. However, that is just what happens when some infilling projects take place into publicly owned watercourses.

We have entrusted others to be the caretakers of this land for our use, and those of the generations to come. I for one have not given the caretakers permission to allow others to destroy or permanently alter that land without just and reasonable cause. Our definition of Use should not include permanently altering or destroying submerged lands without just cause. I have heard, as I am sure many of you have, the phrase " they are not making any more land". Well I don't fully agree with that statement. Every time we infill we create new land. New in the sense that it is dry land; land that we can build upon; walk on; or carry out any number of other land based activities upon.

Unfortunately it is sometimes cheaper to create such lands for these activities by infilling rather than by buying existing land. This can and does happen when there is a need to dispose of material that is of little value from a load bearing perspective e.g. dredge spoils.

Submerged Lands

Unfortunately the price to create such land is high in terms of the natural environment. When we give approval to infill into a watercourse we have given up forever a unique area of this planet commonly referred to as Submerged lands. Submerged lands are some of the most productive and unique areas on the planet particularly the shallow and inter-tidal areas which as it happens are the prime areas involved in infilling.

Global Problem

For many years I have observed infilling activities throughout the Atlantic Region. However we are not alone in this activity, all parts of the world engage in infilling. Recently I read an article where a large modern airport facility complete with, buildings, and runways etc. was build in the middle of the marine environment connected to the mainland by causeway and bridge. Developers of this infill project were very proud of their accomplishment, and, from an engineering perspective that is understandable. However, from the environment prospective, this is less than a desirable accomplishment. Many acres of aquatic habitat were lost forever.

Development

Often, as in this example, infilling has been done in the name of progress or development. I understand the need for development but I feel we have to get away from development at the cost of the aquatic environment. We have to learn to stay within our boundary lines. It does not take much imagination if all we have to do to develop our waterfront is infill.

When I look at recent developments along the Halifax waterfront it appears that a good number of our newer development proposals involved some level of infilling. That is not just development in my books, it's displacement or replacement of marine lands for terrestrial lands.

Sometimes the justification given for some infilling is to provide public access to the waterfront. Public access is a commendable goal but we have to come up with ways and means to accomplish that goal without encroaching into the harbour waters. The simple fact is that no matter what label you put on it, infilling is destruction of the natural aquatic environment.

Impacts

I am not going to spend time pointing out to this learned audience the significance of the various impacts from infilling. Suffice to say - infilling results in habitat loss, compression of the inter-tidal zone to a few centimeters on a pylon or the bank of an infill, significantly reducing productivity. It can result in circulation, velocity and temperature changes, and can contribute to the reduction in clarity, visibility and light penetration into the water column. All of these have a significant impact on aquatic life.

Obviously the footprint of the infill smothers, displaces or otherwise destroys all living life forms. These are often the direct and easily measurable impacts but there are many other impacts not so easily detected that may only appear over time such as changes in species diversity and abundance.

These impacts can effect the existing and potential productivity of the area and the aesthetic values. Unfortunately, impacts from infilling are not restricted to the footprint of the project. Through erosion, runoff, spills and the very presence of the facility impacts can occur well down stream of the site. Such impacts can last for a very long time and the natural balance may never be restored.

The degree of impact on the aquatic environment from infilling is related to many factors such as size, location of the site and the quality of the fill material.

Criteria

I think it is time and extremely important that we rethink how we are using and losing our submerged lands to infilling projects. I think we need to establish criteria that screens all such projects and only approve those that are in the public's best interest, have no other alternative, and are required to support activities that are aquatic based.

It is sad to reflect back and see how much submerged land has been lost to infilling - not only here in Halifax Harbour but throughout our Region. It is equally sad to realize that, in the past, submerged lands have been lost to infill projects that had little public value and the accompanying development could have been constructed on existing dry lands.

I don't mean to leave the impression that I am against all infilling, I am, if the infilling cannot be justified according to some criteria such as what I am proposing above. I understand the needs of the shipping industry to have infrastructure facilities such as wharves and , breakwaters, and seawalls etc. What I find hard to support is the infilling for such things as parking and building lots, storage lands, and even some tourist facilities, particularly when such development could be constructed on existing dry lands.

As I stated above, it's no secret that infilling has taken place from the very beginning of the settlement of Halifax in 1749 and has continued non stop to the present time. One only has to look at the straight lines along much of the Halifax Dartmouth shore to realize that a natural shoreline does not exist - it has been lost over time to development and infilling. What is disturbing today is that we continue to lose submerged lands in the name of development throughout Halifax Harbour. In many cases the loss cannot be justified. There were alternatives on dry land for many developments that have taken place.

Technology

Unlike the past, today we have the ability and the technology to infill with the greatest of ease. With the use of large trucks and other earth moving equipment we can, in one day accomplish what would have taken perhaps weeks to do in the past.

The limits on the earth moving technology in the past was a good thing because otherwise, I am certain, had our forefathers had the equipment we have today the shoreline of many harbours would be significantly different from what they are today.

Over the past 20 or so years 125 infill projects have taken place within Halifax Harbour including the North West Arm and Bedford Basin. Many of these projects were small but some were very large up to 30 acres or even more. Not all of these projects were in support of the marine, or aquatic industry and many had land based alternative sites and thus in my opinion could not be justified.

Given the past two hundred years of harbour development I would think it is fair to say that the cumulative impacts of all these projects has significantly altered this harbour and its ability to support the components of a natural environment.

If we continue on the present coarse, the remaining attributes of this harbour could be seriously affected to the point one might wonder whether this harbour will in time be considered an asset or a liability.

Stakeholders

There are many stakeholders who have an interest in the development, use and management of Halifax Harbour. There are many agencies and commercial operations that

have high hopes for using this harbour as an attraction to the rest of the world to come and spend time and money in Halifax. At the present time the harbour is an attraction, as for example for the Tall Ships gathering.
However, if we don't soon take the necessary steps to protect what we now have, we are placing at risk the value and contribution that this harbour makes to the economy of this Region.

In our past, Halifax Harbour was extremely important to our city and province. It was our lifeline or highway to the rest of the world. We maintained a large commercial shipping and fishing industry in this harbour and the harbour served as a base for a large military force.

Today the harbour is no less important to us. We still have a viable shipping industry and the harbour is still home to the navy. In addition, there is a strong interest in cleaning up this harbour to present it to the world as a tourist and recreational destination. Cruise ships and private yachts come from around the world, and supporters of a host of aquatic activities have a strong interest in making better use of this harbour. The recreational potential is underutilized but we need to take steps now to preserve, protect and enhance what we have.

It is encouraging to note that plans are in the works for sewage control to eliminate the 150ML /day of untreated sewage that is now discharged directly into Halifax Harbour. From my perspective infilling should be high on our priority list as one of the next things we should turn our attention to so we can stick our chests out proudly when we invite the world to come visit us.

Legislation

There are some 13 Federal Acts and half dozen Provincial Acts that apply in one way or another to Halifax Harbour. Some legislation such as the Fisheries Act, section 35 deals with habitat loss including losses caused by infilling projects.

Unfortunately it's not always a simple case of applying the Act to control or stop an infill. One has to have certain conditions such as the evidence to support that an area of a proposed infill is fish habitat.

But surly somewhere in all that legislative mix there is a strong mandate and a commitment to manage, control, and prevent unnecessary infilling.

Conclusion

In conclusion I would strongly recommend that a group of stakeholder and others interested in the well being of this harbour come together to develop criteria, and guidelines for assessing the merits and the need for all future infilling into this harbour.

Future Major Port Development Projects

David Bellefontaine

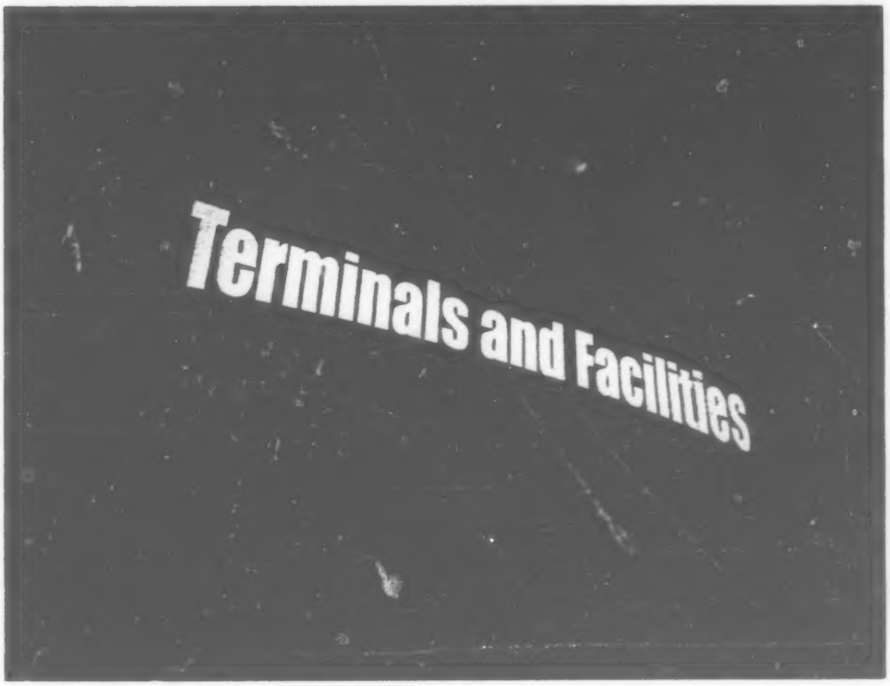
Summary:

Over the past 30 years, the Port of Halifax has invested tens of millions of dollars in infrastructure in order to gain economic benifits for the Region from the ever growing transportation of Canada's imports and exports. More recently, U.S. markets have been gained through more efficient inland service.

The Halifax Port Authority plans to lead in the future development of the Port in an environmentally responsible manner to take advantage of the growing world trade. To accomplish this, new terminal infrastructure will be required in Halifax Harbour to support this new business. The following pages summarize briefly Port facilities, operations and values as presented at the Workshop.

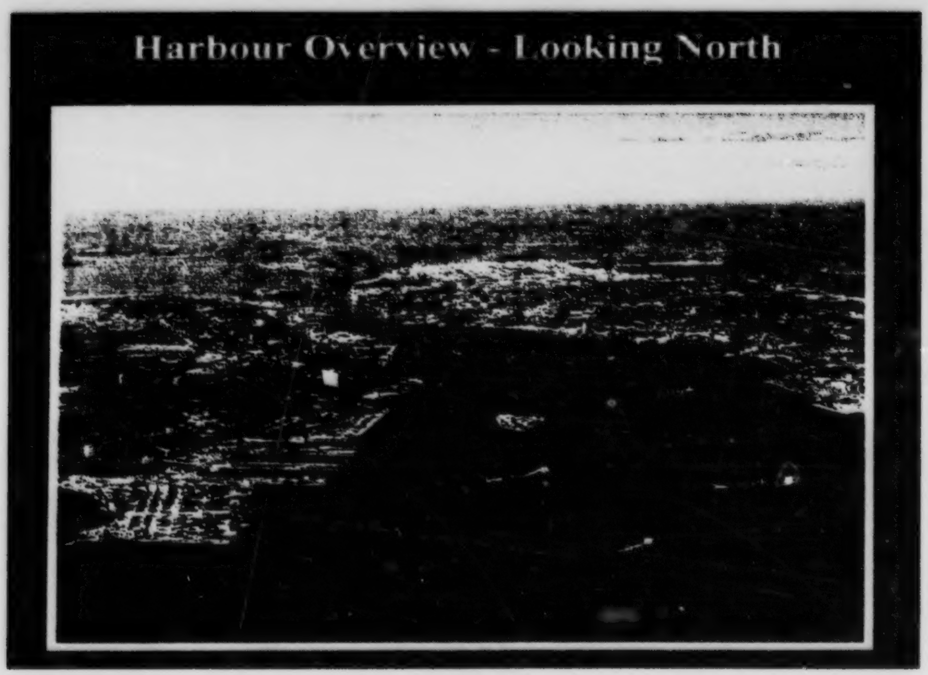
Halifax Port Authority

Figure 1



Terminals and Facilities

Figure 2



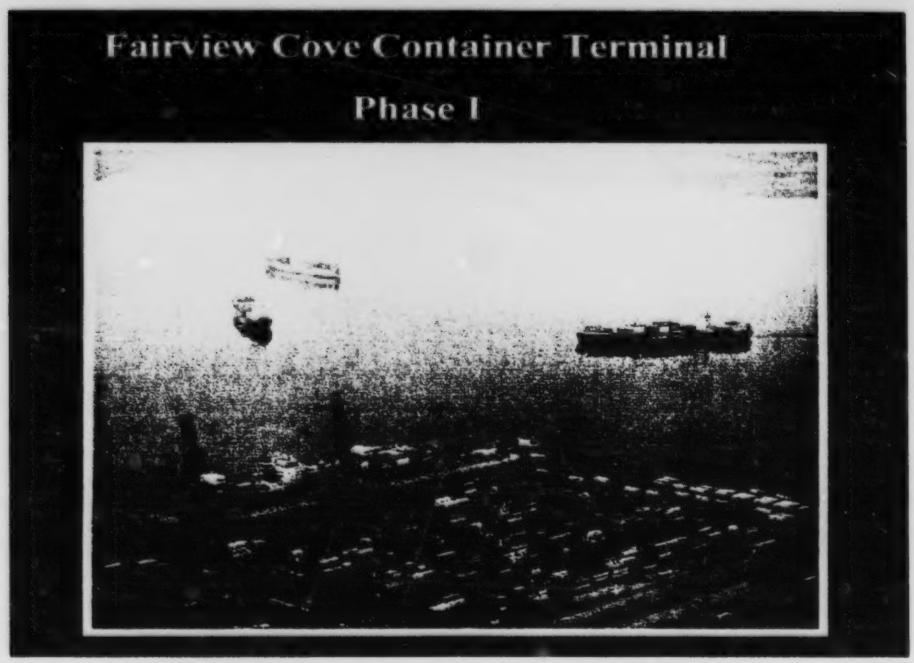
Harbour Overview - Looking North

Figure 3

Fairview Container Terminal

Phase I

Figure 4



Fairview Cove Container Terminal

Phase I

Figure 5

Fairview Cove Container Terminal

Figure 6

Figure 7: Richmond Terminals

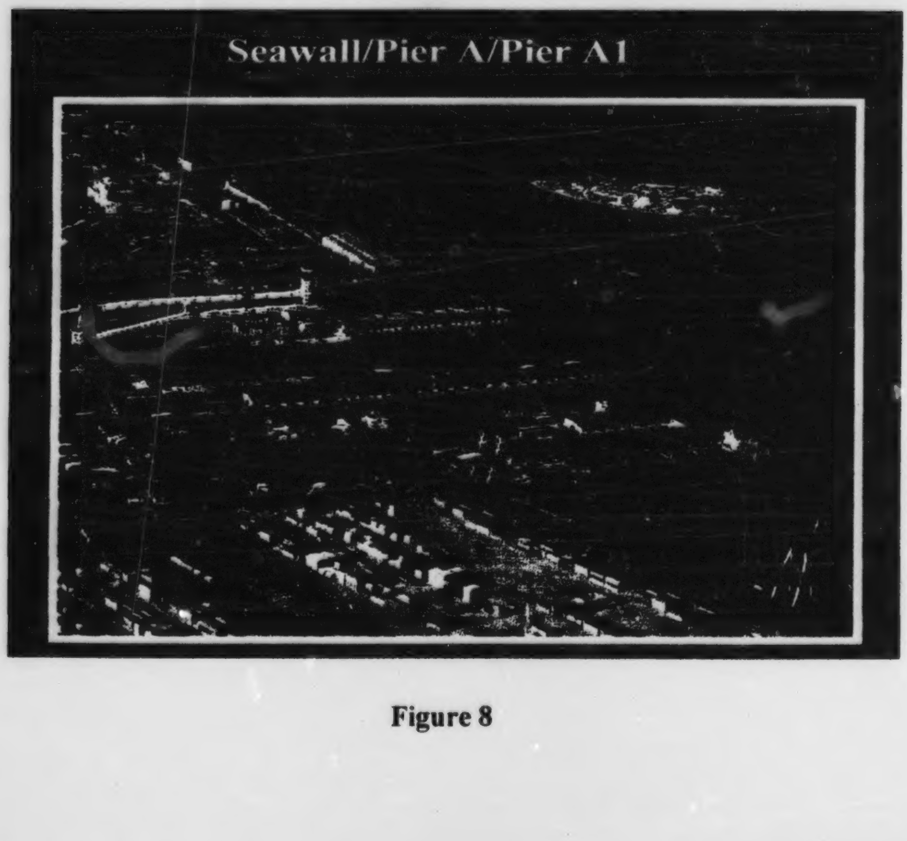
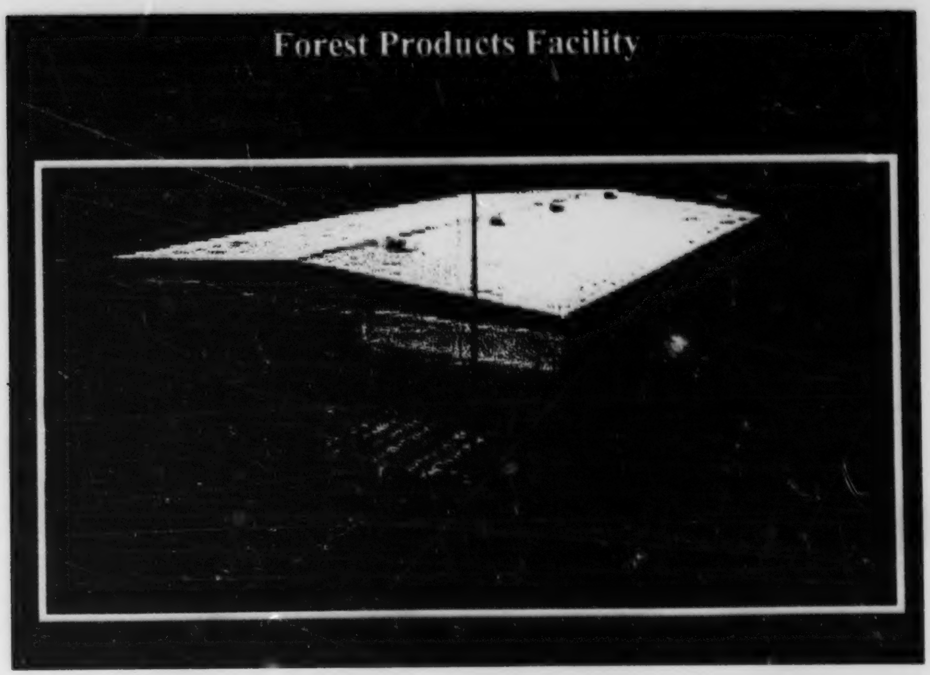
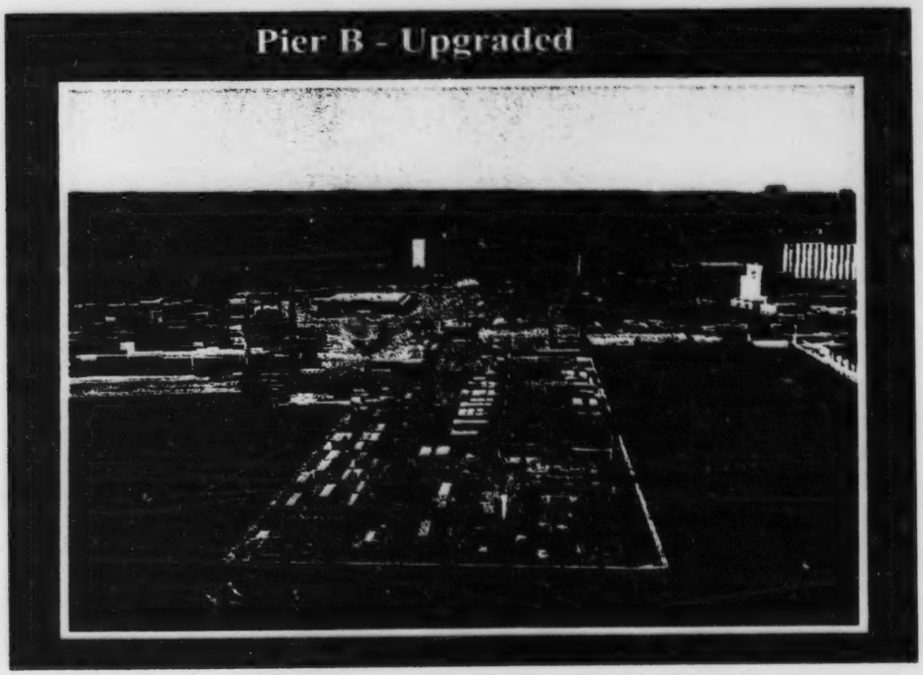


Figure 8



Forest Products Facility

Figure 9

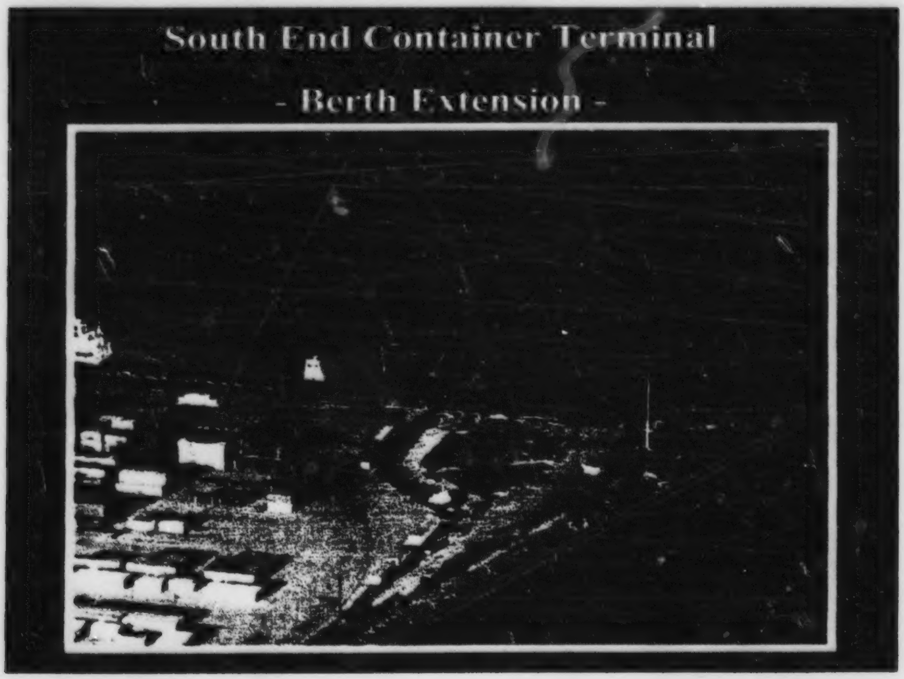


Pier B - Upgraded

Figure 10

South End Container Terminal

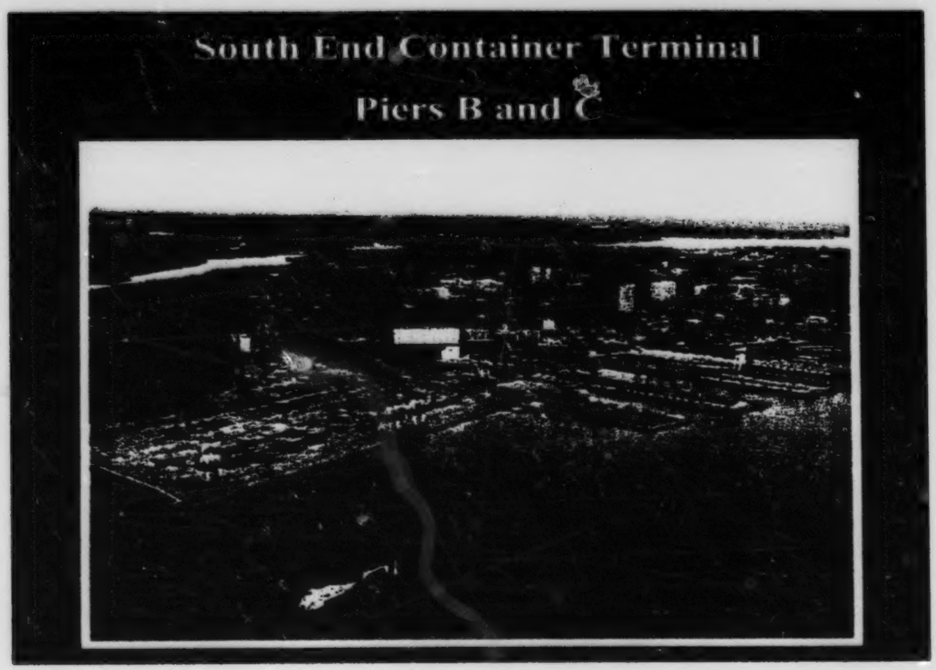
Figure 11



South End Container Terminal

- Berth Extension -

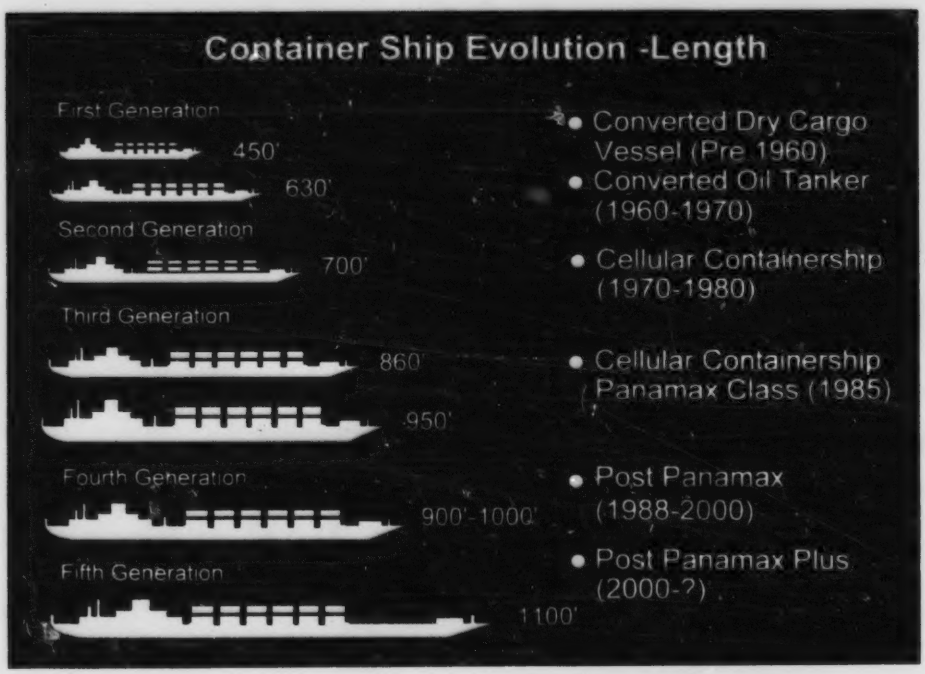
Figure 12



South End Container Terminal

Piers B and C

Figure 13

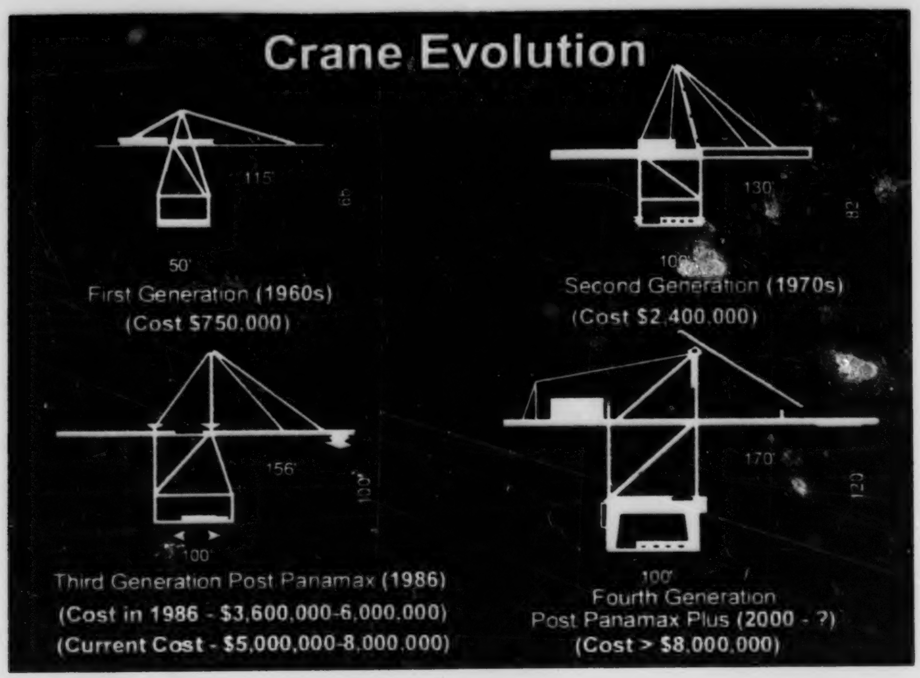


Container Ship Evolution -Length

First Generation
450'
630'
Second Generation
700'
Third Generation
860'
950'
Fourth Generation
900'-1000'
Fifth Generation
1100'

- Converted Dry Cargo Vessel (Pre 1960)
- Converted Oil Tanker (1960-1970)
- Cellular Containership (1970-1980)
- Cellular Containership Panamax Class (1985)
- Post Panamax (1988-2000)
- Post Panamax Plus (2000-?)

Figure 14



Crane Evolution

First Generation (1960s)
(Cost $750,000)

Second Generation (1970s)
(Cost $2,400,000)

Third Generation Post Panamax (1986)
(Cost in 1986 - $3,600,000-6,000,000)
(Current Cost - $5,000,000-8,000,000)

Fourth Generation
Post Panamax Plus (2000 - ?)
(Cost > $8,000,000)

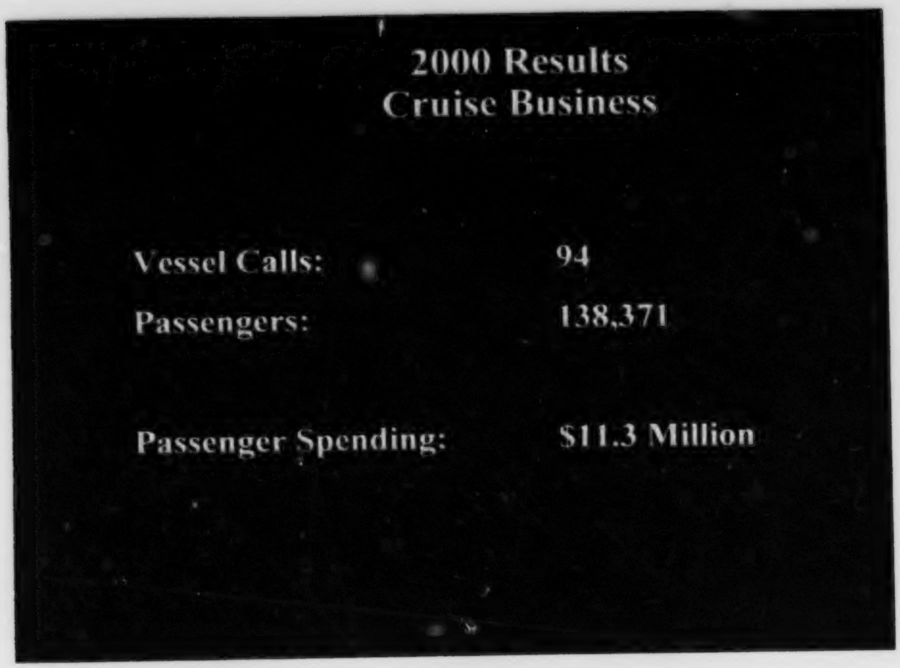
Figure 15

VISION

VISION

TO BE A LEADING
VIABLE NORTH
AMERICAN
GATEWAY PORT

Figure 16



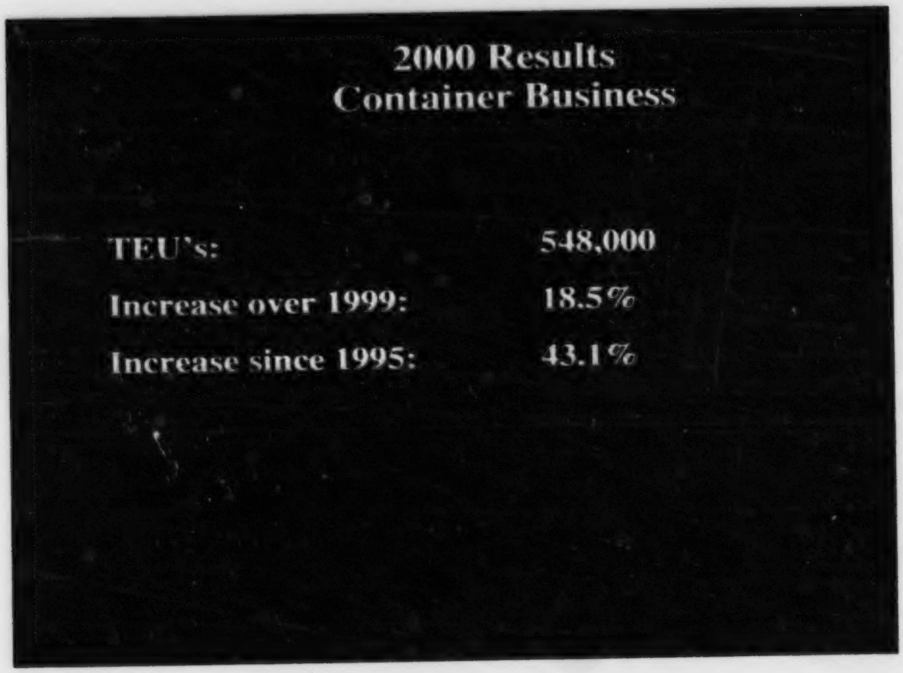
2000 Results
Cruise Business

Vessel Calls: 94

Passengers: 138,371

Passenger Spending: $11.3 Million

Figure 17



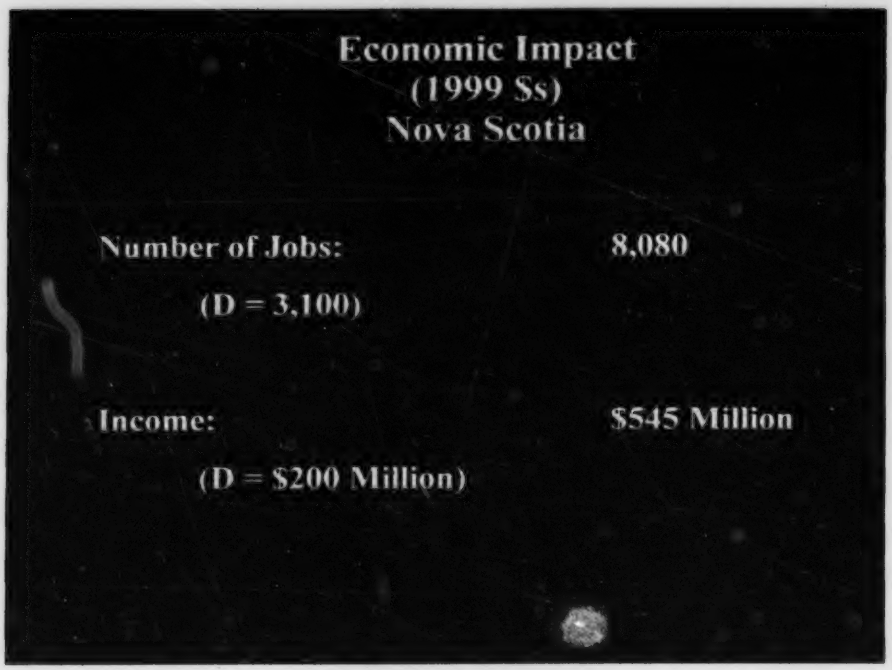
2000 Results
Container Business

TEU's: 548,000

Increase over 1999: 18.5%

Increase since 1995: 43.1%

Figure 18



Economic Impact
(1999 $s)
Nova Scotia

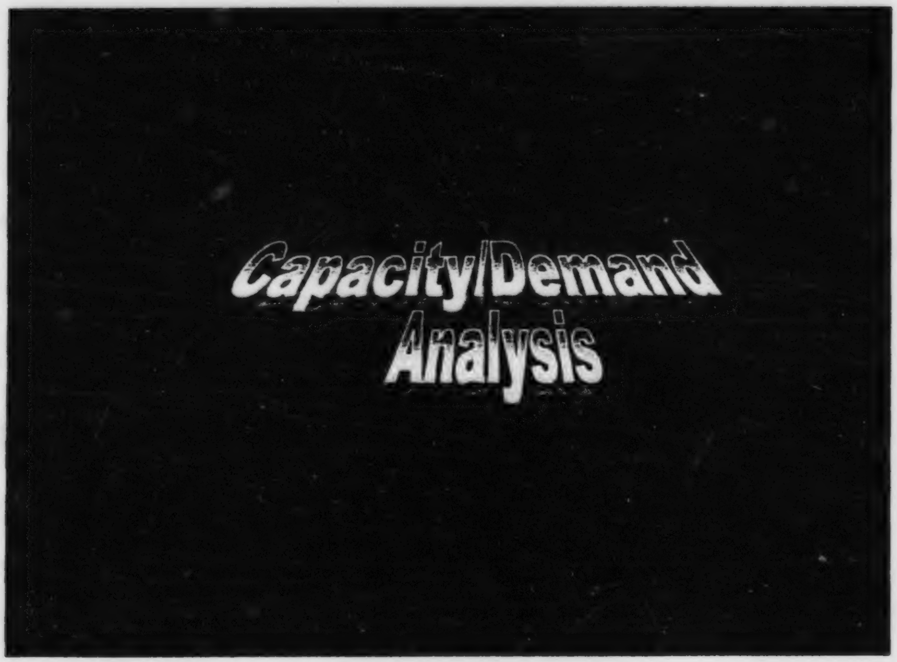
Number of Jobs: 8,080

(D = 3,100)

Income: $545 Million

(D = $200 Million)

Figure 19



Capacity/Demand
Analysis

Figure 20

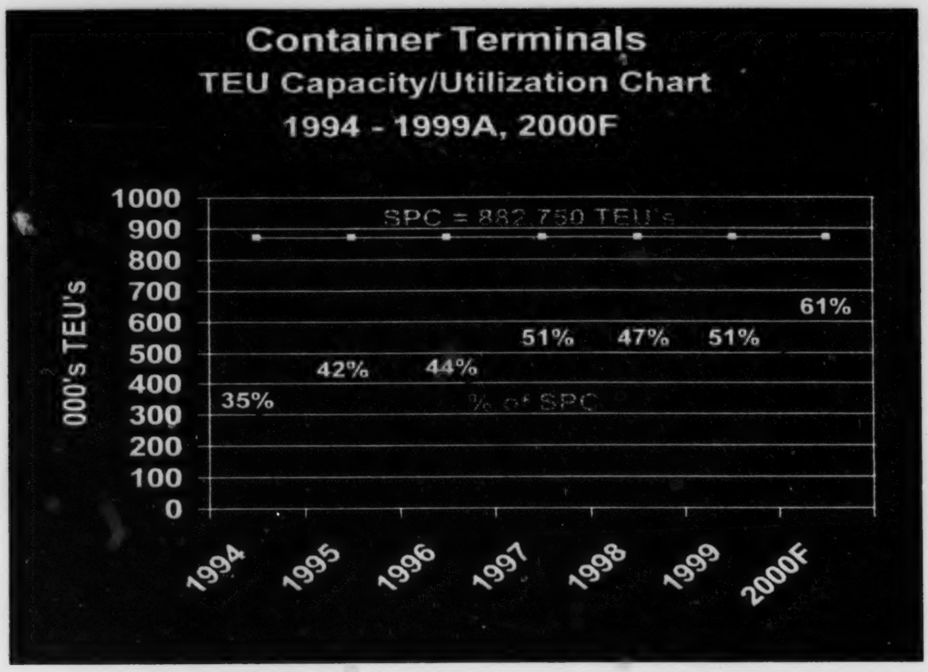


Figure 21

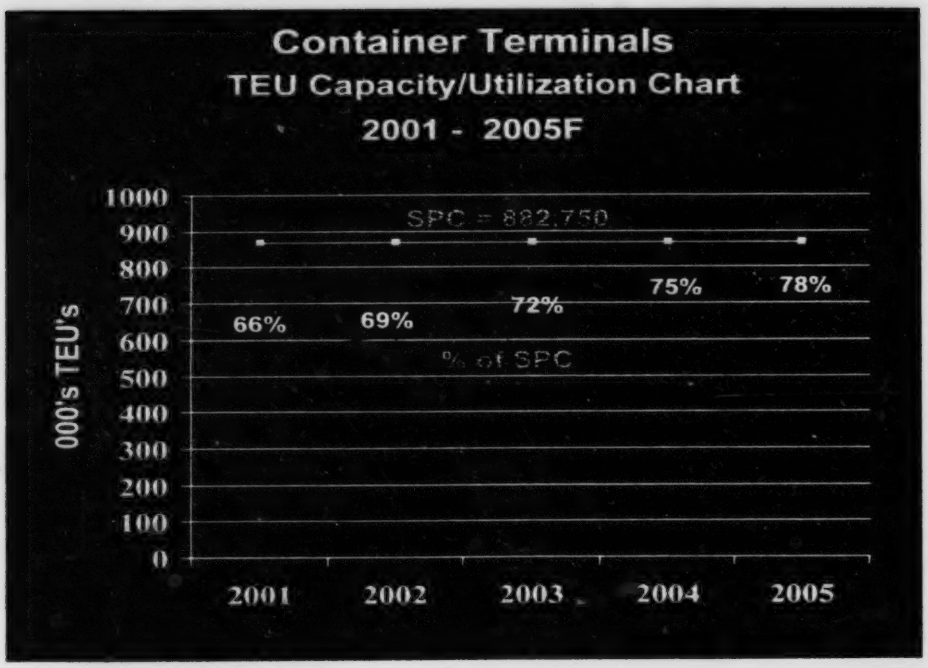


Figure 22

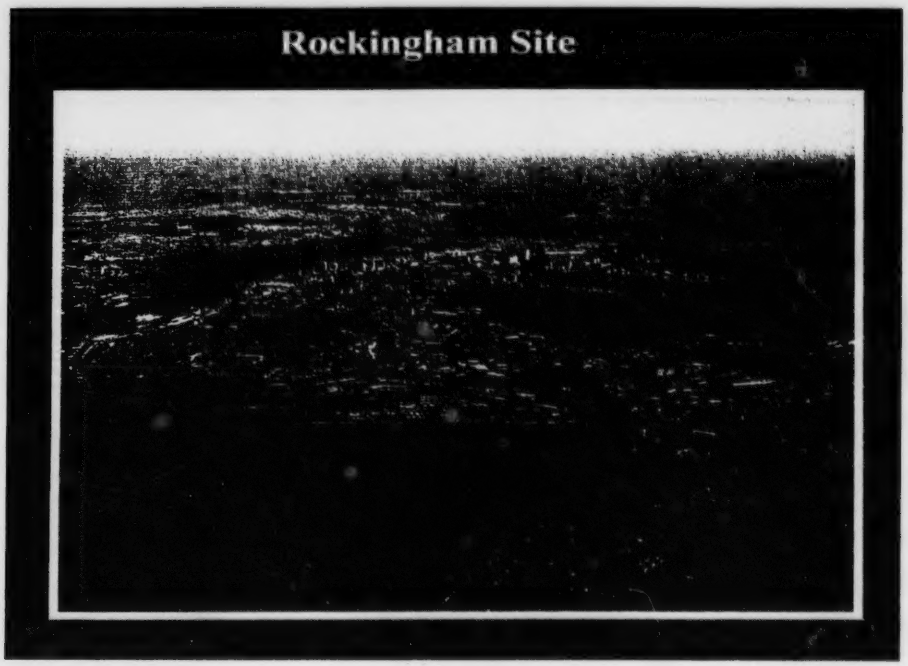
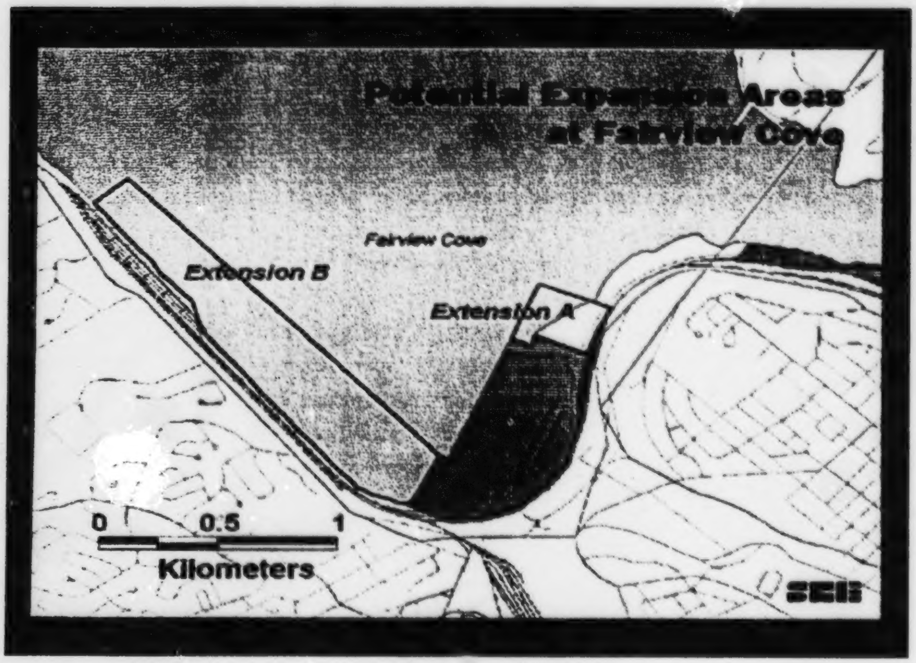

Rockingham Site

Figure 23


Potential Expansion Areas at Fairview Cove

Figue 24

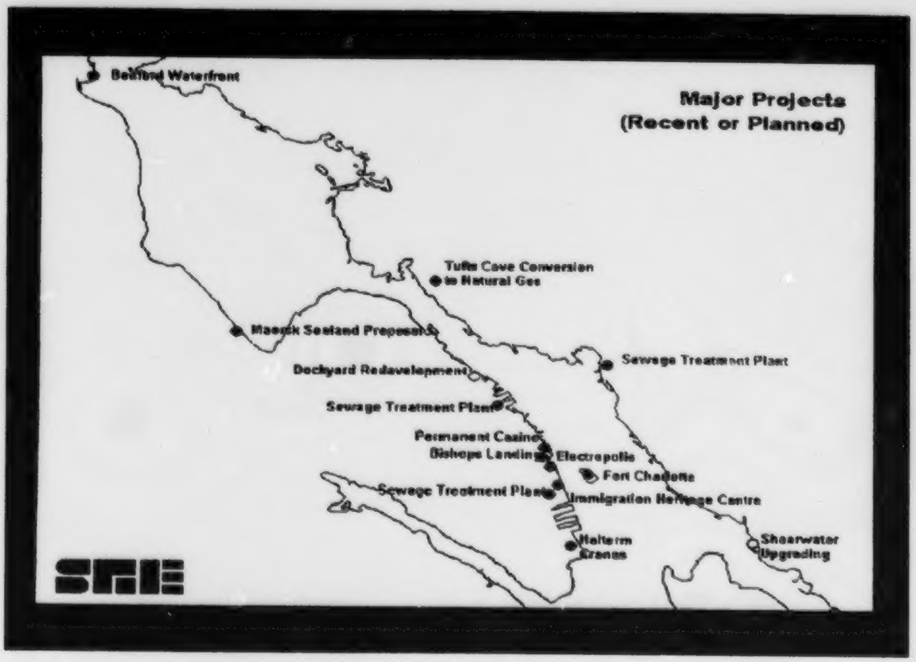


Figure 25

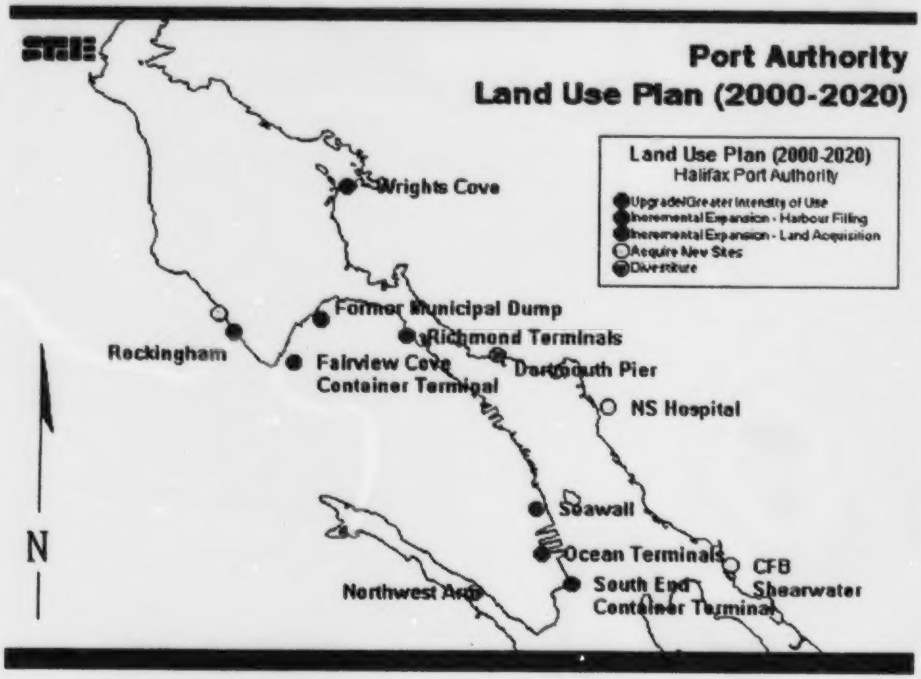

SRE
Port Authority
Land Use Plan (2000-2020)
Land Use Plan (2000-2020)
Halifax Port Authority
● Upgrade/Greater Intensity of Use
● Incremental Expansion - Harbour Filling
● Incremental Expansion - Land Acquisition
○ Acquire New Sites
● Divestiture
Wrights Cove
Former Municipal Dump
Richmond Terminals
Rockingham
Fairview Cove Container Terminal
Dartmouth Pier
NS Hospital
Seawall
Ocean Terminals
CFB Shearwater
Northwest Arm
South End Container Terminal
N

Figure 26

Spectrum of Harbour Activities
Major Future Development Projects

Bill Campbell

Waterfront Development Corporation Limited is a Provincial Crown Corporation with the mandate to rejuvenate the waterfronts of Halifax, Dartmouth, and Bedford. This is the Corporation's 25th Anniversary and during these 25 years the majority of its work has been done in Halifax and Dartmouth. It is only recently that the Bedford waterfront is to come under the jurisdiction of WDCL.

The Corporation achieves its mandate through: property acquisition management and development; marketing and promotion; and coordination and planning of the various waterfronts.

I will deal with each of the waterfronts in turn, identifying major planning and development efforts that are either underway or anticipated in the near to mid term.

Halifax

Over the last five to six years, the Corporation has made major land purchases along the downtown Halifax waterfront, to become what is probably the largest single owner of developable vacant land in downtown Halifax. This land was acquired in order to achieve a balanced development along the Halifax waterfront that promotes mixed uses, which are human in scale and continuous public access along the water's edge. A draft plan of the waterfront has been recently released and discussed at public meetings. This plan prepared in partnership with HRM by EDM, Environmental Design and Management, will provide the overall guidance for development on the waterfront over the next 15-20 years. As many of you are aware, the Corporation has achieved a continuous boardwalk system from the Nova Scotia Casino in the north, to Pier 21, in the south, after an intensive development program over the last, approximately five to seven years. This included such major initiatives as reconstruction of the wharves at Queen's Landing, development of the South Battery boardwalk and heliport, the redevelopment of the Cunard Wharf, and in partnership with Nova Scotia Power Inc., the rejuvenation of the Nova Scotia Power Inc. Wharf, at the old power plant. The project, combined with past initiatives, have created one of the most attractive waterfronts in North America, with over 2.2 million visitors annually.

The vision plan produced by the consultants has shown opportunities for development at the water's edge involving fill and construction of wharves in a number of locations. These include two large finger piers at the Sheraton Hotel, a possible marina at the Nova Scotia Casino, and an area to be filled south of Salter Street, which will become boardwalk and development sites or a park. It is important to point out that what I have just indicated is what may occur and not what will occur. More analysis has to occur in terms of geotechnical analysis of the areas identified, economic feasibility and eventually whether the market will bare these new developments.

Dartmouth

While the jurisdiction of the Corporation in Dartmouth extends from approximately the

MacDonald Bridge south to the Coast Guard facility, the Corporation's land holdings are limited to Dartmouth Cove. Our holdings in Dartmouth Cove include warehousing properties and a water lot. The Corporation has recently prepared a plan for Dartmouth Cove and has attempted to market it for the development of a marine business area. Interest was not strong, however, the Corporation has hopes that in the future, viable economic uses with a marine orientation will take place in Dartmouth Cove, utilizing our current property and water lot.

Recently, the Provincial Government has asked the Corporation to determine the feasibility of taking a more active role in the planning and rejuvenation of the waterfront of Dartmouth, extending beyond our current jurisdiction. While no commitments have been made to date, a strategy for approaching this is being developed. We will be discussing with various stakeholders the need to prepare a coordinated plan for the Dartmouth waterfront area. For example, there are some significant opportunities that need to be addressed. These include the Coast Guard lands, which have been recently announced as surplus by the Federal Government, and the Nova Scotia Hospital lands, which we understand may become surplus in the short to medium term. Both of these areas offer significant opportunity for land based and / or marine based development scenarios.

Bedford

As noted previously, the Bedford waterfront is about to come under the jurisdiction of Waterfront Development Corporation Limited. At your last workshop, Mr. Richard Hattin gave a detailed presentation of the fill operation that has been underway in Bedford for ten years or more, creating land and development opportunities for both the private and public sectors on Bedford Basin. Over the past two years, approximately five acres of new land has been created and it is anticipated that twelve acres of additional land will be created as a result of the filling operation. This fill operation is under continuous environmental assessment. Master plans for the use of this land for mixed use developments and public use were developed in the early '90's and the Corporation is in the process of assessing these plans. At the time of transfer of responsibility of the Bedford waterfront to WDCL, the previous board was in the process of developing a marina. WDCL is continuing this effort and is evaluating submissions from the private sector to develop and manage a marina in the Mill Cove area, adjacent to Convoy Quay.

Over the next five to ten years, the Corporation anticipates the creation of a vibrant active waterfront in Bedford composed of a mix of public and private development.

Questions and Answers
Part 2

Question:
Mr. Ruffman, from your studies, can you tell whether native Indians made any changes to the Harbour shoreline?

Alan Ruffman:
Virtually none as far as I know. In fact there were no changes made by early Europeans (1700's to mid 1800's) when they arrived and settled in area.

Question:
Is there evidence of changes to the harbour area that are not obvious to the naked eye, as an example on the Harbour floor? I'm talking about changes that may have a long-term effect on biota or on natural water movement patterns.

Alan Ruffman:
It is obvious from sonar bottom contour data collected in the harbour that there are man-made physical changes to the Harbour bottom. One can see, for example, where Harbour spoils have been dumped, where the military has dumped old batteries over the years and where 19 Volvos were pushed off the edge of a ship in Bedford Basin. It is not evident whether these things significantly effect biota or water currents.

Question:
Are there any parts of the Harbour or Basin which have not changed dramatically over the years since European settlement began?

Alan Ruffman:
Most areas have been modified, with a few exceptions such as: Admiral's Cove to the Ammunition Dump, McNabs Island and Purcell's Cove shoreline out towards Chebucto Head.

Question:
Mr. Spencer, is infilling a better alternative to blasting to build wharves?

Clarence Spencer:
Yes, infilling is a better alternative when a wharf has to be built and the water is too shallow near shore. Infilling is then used to extend out the wharf into deeper water, rather than blasting to make the water deeper closer to shore. However, there are cases in the Harbour where infilling has been used to support a structure, when in affect the structure should have been moved back from the waters edge to be built on land already there.

Question:
Does extraction of bottom material cause serious long-term problems in the Harbour?

Clarence Spencer:
No, not really. Once the material is removed the bottom will re-stabilize and re-colonize. It should be noted: however, that infilling does permanently destroy that habitat which is covered by dumped material used to infill.

Question:
Should the untreated sewage that flows into the Harbour be considered as infill.

Clarence Spencer:
Yes, at least the solids that are part of the sewage could be considered as infilling.

Question:
Mr. Campbell, would you tell me why the infilling is being done along Bedford Basin near the Mall? Is it to create a bigger tax base for the Municipality and/or to create more residential land?

Bill Campbell:
Infilling in that area does create more residential land and a larger tax base as well. In addition, there was also a need to find an area where dredged material from the mouth of the Sackville river could be dumped. This dredging was carried out to deepen the area in the vicinity of the Bedford Yacht Club which was undergoing infilling from the river which was affecting the mooring options and the Club. It is also hoped that the newly created land will give more public access to the Basin.

Question:
How will creating what I understand is a privately funded Marina complex going to give more Basin access to the public?

Bill Campbell:
The Marina is to be privately funded, but available to anyone who can afford the membership and/or wharfage fees. In addition, there will be free and continuous access to the Basin for the general public via a free boat ramp and water side walkways.

Question:
Why does the downtown Dartmouth area have to be maintained only for industrial development? Why can't it also be used for recreational purposes?

Bill Campbell:
I think the Halifax Waterfront development Board and HRM see the downtown Dartmouth area as one that should be used for both industrial and recreational purposes.

Question:
Mr. Bellefontaine, how do the plans for the harbour you have outlined today fit in with HRM's plans for it's use?

David Bellefontaine:
There is no conflict as far as I know, we meet together regularly in the planning stages and work to reconcile any possible problems.

Question:
With respect to the planned expansions at Fairview Cove, what will be done about the old dump site in the area?

David Bellefontaine:
It is evident that this dump site material must be removed; however, we don't as yet know how or at what cost.

Part 3

Measurable Impacts on Fish Habitat

The Benthic Habitats of the Halifax Harbour Ecosystem: What has been lost?

Annamarie I. Hatcher and Bruce G. Hatcher

Introduction

Edward Cornwallis sailed into an estuarine ecosystem of exceptional biodiversity and massive productivity when he established the city on Halifax Harbour in 1749. The colonists' focus was neither natural history nor conservation, and we have little quantitative scientific record of the extent, productivity or community composition of the marine and coastal habitats of the ecosystem. Two hundred and fifty years later we still struggle with inadequate scientific knowledge of these habitats; but the massive changes during our lifetimes are obvious. It is also possible to reconstruct a vision of the Halifax harbour ecosystem based on our understanding of marine ecology and our knowledge of less anthropogenically impacted ecosystems nearby on the Nova Scotian coast.

The Halifax Harbour system is now an 'urban' estuary which has been receiving the untreated sewage and storm water runoff from the expanding cities of Halifax, Dartmouth and Bedford for over a quarter of the last millennium. At the present time, forty outfalls discharge between 100 and 150 x10^3 m^3 of untreated sewage into the estuary each day. This input represents approximately 50% of the total nutrient input to the ecosystem (Mann, 2000). There are many ways that sewage input may impact the ecosystem structure and function of the receiving waters, and Smith *et al* (1981) identified three of the main ones: (1) Toxic materials or by-products from pesticides, herbicides, chlorine and heavy metals may negatively impact organisms; (2) High biochemical oxygen demand (BOD) from the sewage, with generation of hydrogen sulphide can stress organisms; and (3) Under some circumstances, sewage may represent a 'nutritional subsidy' with a stimulatory effect on the biological community.

Relying on a very limited data set, some observational evidence and a comparison with similar ecosystems we describe aspects of the structure and function of the benthic communities of the Halifax Harbour estuary which have been modified by coastal and watershed urbanization and sewage input. Because the benthic environment is intimately associated with the overlying water and with resident and non-resident biota, we also attempt to examine the impact of changes in structure and function of the benthos on other ecosystem components.

Estuarine subsystems, an overview

Estuaries are inter-connected ecosystems with high rates of biological productivity. There are three main subsystems in most estuaries, which are: (1) the shallow water production zones which include seaweed and seagrass communities, (2) sedimentary subsystems in deeper channels and areas of deposition and (3) the plankton and nekton which move freely between the two fixed subsystems (Odum, 1971). In the shallow water production zones, primary production exceeds respiration and organic material is exported to the depositional areas of the estuary and the continental shelf. In the sedimentary subsystem, respiration exceeds primary production and imported organic material is used. Here nutrients are regenerated, stored and recycled. Through the plankton and nekton components of the water column, nutrients and energy are exchanged with the two fixed subsystems.

Inputs from the water column subsystem to the sedimentary subsystem are dominated by dead and dying phytoplankton cells and the solid excreta of pelagic animals such as zooplankton. The rate of organic sedimentation in Halifax harbour, as measured in sediment traps, ranges from 26.2 to 55.2 g dry weight.$m^{-2}.d^{-1}$ (Novitsky, 1990). This material is either used as a food source for the underlying benthic animals and microbes, or it is laterally transported to areas of deposition by water currents. In Halifax Harbour, mercury anomalies in the sediments suggest that solids discharged at Duffus St. and Tufts Cove are deposited on the SE side of Bedford Basin. Similarly, solids discharged at Pier A can be seen north of George's Island (HRM, 1999).

Depositional Areas: the sedimentary subsystem

Considering the significant amount of anthropogenic particulates which is discharged into Halifax Harbour, the toxic components associated with these particulates and the major depositional sink of Bedford Basin, it is amazing that there have been no detailed studies of sediment transport in the system! However, based on sediment characteristics, it has been deduced that sediment transport is landward in the outer harbour with net input into Northwest Arm and landward along both sides of McNab's Island (HRM, 1999). Areas of deposition within Halifax Harbour estuary include the Northwest Arm, Eastern Passage, three mud patches on the bottom of the inner harbour south of the Narrows and much of Bedford Basin. In these areas, and in the vicinity of all of the outfalls the seabed sediment consists of a fine silt with high organic content. The organic input is largely from sewage-derived particulates and from phytoplankton production boosted by sewage-derived nutrients. Because the organic carbon concentration of these sediments is so high (Buckley & Hargrave, 1989), significant pathways of carbon degradation are through sulphate reduction and methanogenesis. Although these are 'natural' processes, they are far more important now than they were before 1750, due to the present massive anthropogenic input.

The anthropogenic input of organic material to the deep Basin and its subsequent decomposition has caused an oxygen deficit in the bottom waters, documented in 1969 (Platt et al, 1970). Movement of a slug of this anoxic water may have caused an extensive fish kill in the Basin during the fall of 1993, a phenomenon that has been documented in the Adriatic and Baltic seas.

There are many consequences of the anthropogenic displacement of benthic communities along the continuum from aerobic to anaerobic degradation of deposited particulate carbon. As has been found in numerous marine environments, eutrophication produces a low macrofaunal biomass and diversity in the sediments dominated by small, opportunistic polychaetes (Pearson & Rosenburg, 1978). This is the situation in the depositional areas of Halifax Harbour (Platt et al, 1970; HRM, 1999).

There are more subtle changes with the move along the aerobic to anaerobic continuum. With less oxygen available at the sediment surface, nitrification may be less important, and reduced nitrogen (such as ammonium) more common. Net sedimentation of phosphorus may decrease, as lability in sediments increases with increasing anoxia. The bioavailability of various contaminants (such as heavy metals) also positively co-varies with availability of oxygen. With changes in the character, amount and ratio of nutrients regenerated by the benthos, and the bioavailability of contaminants such as copper, changes will also occur in the productivity and species composition of the phytoplankton communities and the benthic algae. These changes will translate to various impacts up the food chain. We have little or no data available on these processes in the Halifax Harbour ecosystem.

Zones of higher water exchange

Areas which are devoid of fine sediment can be assumed not to be areas of deposition. In Halifax Harbour these areas of high water exchange, strong bottom currents and wave action occur in the Narrows, the entrance to Bedford Bay, Ives Knoll, the outer harbour southeast of McNab's Island, and in many shallow coastal areas to a depth of 10 m. (HRM, 1999). In the outer harbour these zones of bedrock and cobble bottom are covered with dense biomass of macrophytic algae such as *Fucus, Ascophyllum* and *Laminaria spp.* (Hargrave *et al*, 1989; Mann, 2000). In the inner harbour, Bedford Basin and Northwest Arm by contrast, these substrates are covered with a dense assemblage of filter-feeding bivalves, dominated by the mussel, *Mytilus spp.*. Did these habitats support communities more similar to those of the outer harbour before urbanization? A classic study of intertidal zonation in the inner harbour was conducted in 1948 by Stephenson and Stephenson (1972). They characterized the biota as intermediate between a fully developed open-coast population and one in a deep inlet (i.e. fjord). They describe a community dominated by *Fucus, Ascophyllum* (rockweeds), *Laminaria* (kelp) and *Ralfsia* (seaweed) with many associated invertebrates such as mussels, limpets and barnacles.

The intertidal and shallow subtidal areas of Bedford Basin where macroalgae are sparse and mussels have predominated since the 1980's were once the typical beds of *Fucus* and *Ascophyllum* as found in adjacent bays. The change occurred over the period of the mid 1960's to the late 1980's (personal observation). Riley (1974) noted the disappearance of many formerly-common intertidal macroalgal species from the harbour.

The changing character of shallow rocky substrates in the inner harbour, Northwest Arm and Bedford Basin from the typical autotrophic community (i.e. dominated by seaweeds) to a heterotrophic community (i.e. dominated by sessile filter feeders such as mussels) is a typical community-level response to excessive inputs of organic particulates from sewage (Smith *et al*, 1981). In Kaneohe Bay, Hawaii, for example, it was found that the nutritional subsidy of sewage-derived particulates allowed faster growth of the filter feeders, and conferred a competitive advantage in occupation of space (Smith *et al*, 1981).

The changes in the shallow benthos observed in Halifax Harbour could be mediated by many factors such as overgrowth of the seaweeds by epiphytes (Riley, 1974), shading of existing seaweeds by faster growing phytoplankton, or physiological responses of the seaweeds to toxic components of the sewage (Pearce, 1991). As well as the decrease in the macroalgal inhabitants of the intertidal and shallow subtidal areas a significant area of seagrass (*Zostera marina*) has been lost from parts of Bedford Basin and Eastern Passage.

Seaweed and seagrass beds in intertidal and subtidal areas of marine and freshwater environments are highly productive systems, with an ecological significance much greater than their areal extent. The large biomass and impressive areal productivity of these macrophytes makes them efficient concentrators and convertors of inorganic nutrients. In addition to this function, macrophyte assemblages provide essential habitat for many sessile and motile animals. These include commercially important species of fish and invertebrates, and many components of the food webs that support them.

The pivotal roles of macrophytes in aquatic communities are universal. For example, in areas of the Great Lakes littoral habitats with high abundance of submerged macrophytes have significantly higher density, diversity and production of fish species (Randall *et al*, 1996). Macroalgae is known to be a preferred habitat for juvenile cod, providing excellent cover from predation (Keats *et al*, 1987). Many species of marine fish occur in shallow coastal areas as juveniles, using the macrophyte beds as nursery areas. The subsequent movement to deeper water with increasing size, common among many fish species, is referred to as 'Heincke's Law' (Wimpenny, 1953). In this context it is pertinent to ask how anthopogenic changes in the coastal and marine environment of Halifax harbour have affected fish habitat.

Fish Habitat

The fish's habitat consists of water and its interfaces. The main physical interfaces are those between water and the seabed, the sea surface, and their confluence: the sea shore. Other interfaces exist within the water column, such as a pycnocline or a front where freshwater meets seawater. The physical interfaces are not always sharp, nor fixed in space or time. Halifax Harbour estuary, with 70 km^2 surface area, 1.6 km^3 of water, 150 km of shoreline, 0.5 km^2 of intertidal zone, 83 km^2 of seabed, and 0.001 km^3.y^{-1} of freshwater input is rich in the fundamental units of fish habitat. Pronounced seasonality and the complex geomorphology, topography and hydrology of the harbour make it one of the most extensive and diverse coastal fish habitats on the Atlantic shore of Nova Scotia (rivaled perhaps only by Mahone and St. Margaret's Bays).

The defining feature of fish habitat is the interface between biological and physical attributes. Biology concentrates at physical interfaces, smearing them, modifying their structure and modulating the processes of transport and exchange. The roles of biological components of fish habitat are particularly important in the epibenthos. In subtidal areas of the coastal zone, the sedimentation of organic material originating in both the water column and on land fills sediment interstices, steepens REDOX profiles and strengthens benthic-pelagic coupling. The growth of kelp, seagrass, sponges, corals and other colonial or aggregating invertebrates expands the benthic boundary layer, baffles near-bed currents, creates shelter space and provides food to both grazing and detritivorous fish and invertebrates. Table 1 outlines the attributes of fish habitat. It follows that fish habitat must include both physical and biotic attributes and their interactions. i.e. the concept of fish habitat is an ecosystem concept.

Table 1: Attributes of fish habitat in Halifax harbour

Benthic Habitat Type	Interfaces	Structuring processes	Characteristic spps.
Estuarine channel	FW:SW:SL	River flow, mixing	Anadromous fish
Salt marsh (intertidal)	FW:SW:T	Runoff; tides, PP	*Spartina*, molluscs
Beach (")	SW:IS:T	Wave disturb$^{nce.}$, erosion,	Meiofauna, bivalves
Mud flat (")	SW:IS:A	Resuspension, R-C-P-D	Microalgae, infauna
Rocky intertidal	SW:HB:A	Dessication, R-C-P-D	Algae, sessile inverts.
Sand sheet (subtidal)	WC:IS	Waves, DS, resuspension	Meiofauna, bivalves
Eelgrass meadow (")	WC:SS:B	PAR, NS, PP, R-C-D	Zostera, bivalves
Kelp bed (")	WC:HB:B	PAR, NS, PP, R-C-D	Algae, motile inverts.
S.U.-dominated barrens	WC:HB	DS, R-C-P-D, pathogens	*Strongylocentrotus*
Deep outcrop (dysphotic)	BW:HB	Currents, DS, R-P-D	Sponges, corals
Deep sediments (")	BW:IS	Resuspension, DS,R-P-D	Meiofana, worms

A=Atmosphere; B=Biota; BW=Bottom Water; DS=Detritus Supply; FW=Fresh Water; HB=Hard Bottom; IS=Interstitial Space; NS=Nutrient Supply; PAR=Photosynthetically Active Radiation; PP=Primary Production; R-C-P-D=Recruitment, Competition, Predation & Disturbance; SL=ShoreLine; SS=Sediment Surface; SW=Surface seaWater; T=Terrestrial; WC=Water Column.

A reconstruction of the fish habitat of the Halifax Harbour ecosystem

The application of ecosystem concepts to fisheries science has led recently to the formal recognition of essential and critical fish habitats. Essential habitat is that which must exist if a fish or invertebrate population is to complete its life cycle. Critical habitat is that which would jeopardize the survival of a fish population or community if removed. The maintenance of essential fish habitat is now accepted as a key management goal not only for the conservation of exploited fish resources, but also for the preservation of marine and coastal biodiversity. The latter reflects the obvious fact that fish habitat is also habitat for a great variety of other organisms, and the term is really just a way of describing marine ecosystems in the context of the life form that is best known and of most direct value to humans.

The geomorphology and oceanography of Halifax harbour make it (with its associated catchment) a well- delineated ecosystem. It is appropriate therefore to use the quality of fish habitat as a surrogate for the health of the Halifax harbour ecosystem. This is just as well, because there is precious little economic value to the fisheries resource of Bedford Basin and the inner harbour at present

Fish landings and habitat quality

There was undoubtedly a time when the fish resources of Halifax Harbour were the most valuable aspect of the ecosystem to humans. Perhaps the most reliable indicator of ecosystem health is the population density of aboriginal people. First nations people would not have concentrated in the Halifax catchment for hundreds of years because of its climate, soil or strategic value. There were far more benign and productive terrestrial environments available in northern Nova Scotia. The juxtaposition of habitable land areas and a highly productive marine ecosystem attracted humans to Halifax harbour and sustained their modest populations for centuries.

Unlike the aboriginal people, European colonists chose Halifax harbour as a settlement place for its strategic location and military defensibility. The primary value of the harbour to them was as a route between Halifax, Dartmouth, Bedford and the rest of the world, not as a producer of fish. Yet, the anecdotal reports of the early settlers leave no doubt that the harbour provided a surfeit of cod, haddock, pollock, flounder ("sole"), shad, herring, salmon, lobster, and clams to the resident populations for at least the first century following colonization. In more recent times, catch statistics show that landings of cod and lobster from the outer harbour, and herring from the inner harbour and Basin were very substantial during the last half of the 20th century. Although the landed value of catches from harbour fisheries remains significant (largely due to the extremely high value of lobster), the biomass of these stocks has declined markedly during the past 20 years, presumably due to overfishing and habitat degradation.

The records of the salmonid hatchery at the mouth of the Sackville river bear testimony to the abundance and value of those sensitive, anadromous species in the harbour. The dominance of such indicator species in the diets of aboriginal people before European colonization, and their present scarcity provide the most informative vision of what the environment of Halifax harbour was like prior to urbanization, and what habitats have been lost.

A mere 500 years ago the geomorphology, eustatic sea level, tides, wind-driven circulations, surface irradiance, and links to offshore waters were indistinguishable from those of today. None of the anthropogenic changes in the harbour have significantly altered these fundamental physical attributes of the ecosystem. What has changed in the period since the arrival of Edward Cornwallis is the physical and community structure of the land-sea interface, the amount and nature of terrestrial inputs, and the quality of the water and sediment. The net result has been a substantial loss of littoral habitat.

In Table 2 we make estimates of change in the abundance of marine habitat types in the inner and middle harbour, Eastern Passage, the Northwest Arm and Bedford Basin during the last 250 years. We have not attempted such calculations for the outer harbour, which appears to be much less impacted by development. These are crude estimates based on the interpretation of old charts and aerial photos compared with modern habitat maps (themselves inadequate for the littoral zone). Simplifying assumptions concerning the relationship between shoreline slope and habitat area, and the effects of sedimentation have been made, and we present these as a challenge for more rigorous habitat mapping and historical interpretation rather than as definitive metrics.

The time course of change in the availability of various fish and their habitats mirrors the growth of the human population around the harbour. The largest and most rapid degradation apparently occurred after the second world war, but local alterations of littoral habitats by shoreline construction along the inner harbour, NW Arm and west side of the Bedford Basin progressed through the industrial revolution. Jetty construction, shoreline armoring and abutments and, more recently, land reclamation projects are estimated to have converted about 40% of the harbor's intertidal and shallow subtidal habitat from marsh, beach, mud flat, seagrass bed, rocky intertidal or macro-algal beds into vertical walls or steep boulder slopes. The destruction or degradation of shallow macrophyte communities (i.e. marsh, seagrass and kelp beds) is the most serious direct impact of coastal development on fish habitat in the harbour, because of the disproportionate importance of these structuring communities in providing food and shelter to both juvenile and adult fish and invertebrates. Their disappearance from the Eastern Passage, NW Arm, inner harbour and Bedford Basin constitute the loss of essential habitat for many marine species.

Table 2: Estimated loss of habitats in the inner and middle Halifax Harbour, Eastern Passage and Bedford Basin.

Benthic Habitat Type	**1750 Area**	**2000 Area**	**Habitat Lost**	**Notes**
Estuarine channel	> 150 ha	30 ha	> 80 %	J. Bruin, 2000
Salt marsh (intertidal)	20 ha	0 ha	100 %	Wright's Cove area
Beach (")	15 ha	5 ha	67 %	< 20% gradient
Mud flat (")	37 ha	240 ha	0 %	Dartmouth & Arm
Rocky (")	22 ha	17 ha	23 %	Wharves & walls
Sand sheet (subtidal)	> 115 ha	115 ha	significant?	Fader et al, 2000
Eelgrass meadow (")	> 200 ha	< 10 ha	> 95 %	Dart. Bedford & Arm
Kelp bed (")	> 210 ha	< 5 ha	> 98 %	Rocky margin < 10m
S.U.-dominated barrens	> 425 ha	< 295 ha	> 78 %	" " >10<30m
Deep outcrop (dysphotic)	> 85 ha	95 ha	significant?	Fader et al, 2000
Deep gravels & seds.(")	>1300ha	>1780ha	0 %	" " " "

The most pervasive mechanism of anthropogenic change in the marine habitats of Halifax harbour is alteration of the watershed. This has greatly increased the input of inorganic and organic material to the waters and sediments of the harbour. The clearing of forest from the harbour's catchment, and of riparian vegetation from the Sackville river catchment can be predicted from studies elsewhere to have increased by a factor of 3 to 7 the inputs of terrestrial runoff and the sedimentation to low energy environments. Nowhere is this effect more apparent in the harbour than at the mouth of the Sackville River. Local records may be used to infer a sediment accumulation rate exceeding 2 $mm \cdot y^{-1}$ over the last half century. The effect is to smother hard bottom communities, divert river and tidal flows, and hinder access to estuarine habitats by anadromous and catadromous species. Other areas of the harbour subjected to extra-ordinary increases in sedimentation include Eastern Passage, Wright's Cove and the upper reaches of the NW Arm.

In all three areas as mentioned above, once extensive seagrass meadows have been buried in terrigenous sediments, representing significant losses of critical fish habitat. We estimate that over 90% of the seagrass habitat in the Halifax Harbour estuary has been lost since the advent of European colonization.

The last documented commercial catch of Atlantic salmon in the Halifax Harbour-Sackville River ecosystem was in the 1960's. The elimination of this sensitive and characteristic species from the ecosystem is the result of habitat degradation rather than simple over-exploitation. It serves as a benchmark for habitat change.

Benthic habitat function

Along with increased terrigenous inputs resulting from coastal development have come the inputs of human and industrial wastes commensurate with substantial population growth. As toilet for Halifax's population, the harbour now receives at least 1000 times more organic material and infinitely more heavy metals and hydrocarbons that it did before 1750. Given that the capacity of the system to flush these contaminants has not increased, and has probably decreased slightly as a result of develop-ment due to shoaling and friction, the materials have accumulated in sediments and biota. The large pool sizes are reasonably well documented, and comprise a biogeochemical and trophodynamic "flywheel" that has significant negative implications for attempts to restore critical habitat in Halifax harbour. The dominant effects of these inputs on marine habitat result from the stimulation of microbial productivity in the water column and sediments. The associated phytoplankton and bacterial biomass reduce the penetration of phtosynthetically active radiation through the surface layer, and the concentration of oxygen in the deeper and benthic layers. The documented growth of the anoxic layer at the bottom of Bedford Basin is one of the better measures we have of the progressive change in marine benthic habitat of the harbour associated with anthropogenic development. It may actually represent a new habitat that was not present 250 years ago. Similarly, the continuous disposal of large artifacts in the harbour in the form of ships, autos and machinery represents new structural habitat (i.e. artificial 'reefs') that is known to aggregate both sessile and mobile fauna in areas of featureless sediment where topographical relief is limiting to biomass. Whether these anthropogenic increases in fish habitat area offset the decreases in hard substrata, topography and rugosity resulting from sediment blanketing is difficult to estimate, but we doubt it...

Summary and Conclusions

The lines of evidence developed here, which are largely inferential and anecdotal, suggest that the Halifax Harbour ecosystem that Edward Cornwallis sailed into a quarter millennium ago would have been a prime candidate for a global biosphere reserve. The dense juxtaposition of environments terrestrial and marine, fresh and salt, deep and shallow, exposed and sheltered, hard and soft within a large, well-delineated, geologically recent and fully vegetated catchment provided a richness of fine-grained habitat that supported a diversity of species and communities. In addition, a production of biomass was supported that we can only imagine by reading historical anecdotes and examining the few modern, near-pristine environments remaining on this coast of Nova Scotia.

Due to cumulative anthropogenic modification of shorelines and inputs of untreated sewage for over two centuries, the extent, diversity, structure and function of the benthic habitats and the biotic communities they support has changed profoundly in the Halifax Harbour estuarine ecosystem. In depositional areas of the estuary a smothering input of particulate organic material has pushed benthic decomposition processes far toward the anaerobic end of the continuum. Significant meadows of seagrass have been replaced by sediments with low biomass of primary producers and low diversity of animals, dominated by worms. In the intertidal and shallow subtidal areas of rock and cobble, dense assemblages of macroalgae have been replaced by a community dominated by sessile, filter feeding invertebrates.

Because of the lack of historical data, it is impossible to accurately quantify these losses of habitat, but the unequivocal loss of the littoral habitat created by benthic macrophyte communities is considered to be highly significant because of the importance of these areas as 'nursery areas' for a myriad of marine species, including commercially important fish.

We will never fully know what we have lost in developing Halifax Harbour as an urban center. We do know what we have gained in profits and life styles, and we can be sure that non-human species have paid for those gains. The remaining challenge is to correctly predict and then accurately measure the effects of repaying our debt to the other residents of the harbour as we finally clean up our act.

Literature Cited

Bruin, J. 2000. Freshwater stream losses in the Halifax Harbour watershed. *In: Ducharme, A. (ed). Preserving the Environment of Halifax Harbour; Fisheries and Oceans Canada and Halifax Regional Municipality. Workshop = 1, pp.171-174.*

Buckley, D.E. & Hargrave, B.T., 1989. Geochemical characteristics of surface sediments. *Chap. 1 in: Nicholls, H.B. (ed). Investigations of Marine Environmental Quality in Halifax Harbour. Can. Tech Rep. Of Fish. And Aquat. Sci. 1693., pp: 9-36.*

Fader, G., 2000. Halifax Harbour: marine geology, anthropogenic characteristics and management. *In: Ducharme, A. (ed). Preserving the Environment of Halifax Harbour; Fisheries and Oceans Canada and Halifax Regional Municipality. Workshop = 1, pp.28-35.*

Hargrave, B.T., Peer, D.L. & Wiele, H.F., 1989. Benthic Biological Observations. *Chap. 2 in: Nicholls, H.B. (ed). Investigations of Marine Environmental Quality in Halifax Harbour. Can. Tech Rep. Of Fish. And Aquat. Sci. 1693., pp: 37-45.*

HRM (Halifax Regional Municipality), 1999. The Halifax Harbour Solutions Project Provision of Sewage Treatment. Project description for consideration under the Canadian Environmental Assessment Act (CEAA) Coordination regulations. *(unpub. document)*

Keats, D.W., South, G.R. & Steele, D.H., 1987. The role of macroalgae in the distribution and feeding of juvenile cod (*Gadus morhua L.*) in inshore waters of eastern Newfoundland. *Can. J. Zoology 65: 49-53.*

Mann, K.H., 2000. The living estuary. *In: Ducharme, A. (ed). Preserving the Environment of Halifax Harbour; Fisheries and Oceans Canada and Halifax Regional Municipality. Workshop # 1, pp. 9-13.*

Novitsky, J.A., 1990. Evidence for sedimenting particles as the origin of the microbial community in a coastal marine sedimentary basin. *Mar. Ecol. Prog. Ser. 60: 161-167.*

Odum, E.P., 1971. Fundamentals of Ecology. *W.B. Saunders Co., Philadelphia, 574 pp.*

Pearce, R.J., 1991. Management of the marine environment in Western Australia: an ecosystem approach. *Mar. Pollut. Bull. 23: 567-572.*

Pearson, T.H., & Rosenburg, R., 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment . *Oceanogr. and Marine Biology Annual Review 16: 229- 311.*

Platt, T., Conover, R.J., Loucks, R., Mann, K.H., Peer, D.L. Prakash, A., Sameoto, D.D., 1970. Study of a eutrophicated marine basin. *FAO Technical Conference on Marine Pollution and its effects on living resources and fishing. Rome, Italy.*

Randall, R.G., Minns, C.K., Cairns, V.W. & Moore, J.E., 1996. The relationship between and index of fish production and submerged macrophytes and other habitat features at three littoral areas in the Great Lakes. *Can. J. Fish. Aquat Sci. 53 (Suppl 1): 35-44.*

Riley, G.A., 1974. Report to the department of the environment, province of Nova Scotia, on the Oceanography of the Halifax Inlet in relation to problems of sewage disposal. *Inst. Environ. Stud., Dalhousie Univ., Halifax., N.S., 44 pp.*

Smith, S.V., Kimmerer, W.J., Laws, E.A., Brock, R.E. and Walsh, T.W., 1981. Kaneohe Bay sewage diversion experiment: perspectives on ecosystem responses to nutritional perturbation. *Pac. Sci. 35 (4); pp 279-397.*

Stephenson, T.A. & Stephenson, A., 1954. Life between tide-marks in North America, III B. Nova Scotia and Prince Edward Island: the geographical features of the region. *J. Ecol. 42: 46-70.*

Stephenson, T.A. & Stephenson, A., 1972. Life Between Tidemarks on Rocky Shores. *W.H. Freeman & Co., San Francisco. 425 pp.*

Wimpenny, R.S., 1953. The plaice. *Edward Arnold & Co., London, U.K.*

Changes in Planktonic Microbiota

William K.W. Li

Introduction

In recent decades, many coastal waters all over the world have experienced remarkable changes from their historical norms. Ecosystems at the land-sea margin are forced by natural and anthropogenic processes originating from the coastal ocean, the atmosphere, and the land. These processes include nutrient enrichment, chemical contamination, hydrologic engineering, aquaculture, fishing, translocation of nonindigenous organisms, and climate change. Unfortunately, it is often not possible to discern a robust functional relationship between ecosystem forcing and response. For example, annual nutrient loading in San Francisco Bay is higher than in Chesapeake Bay, yet it is the latter that responds with high phytoplankton biomass, high primary production and hypoxic bottom waters. Such complexities have given rise to a more refined understanding of coastal ecosystems. This approach explicitly recognizes two important attributes of such ecosystems: first, that each system has specific features that modulate the response, and second, that there is a complex suite of direct and indirect responses (Cloern, 2001).

Halifax Harbour is a "living estuary": it is a functioning ecosystem that has preserved most of its basic functions (Mann, 2000). Although the harbour is apparently less biologically diverse and less productive of fish and shellfish than in the past, there has yet been no rigorous assessment of long-term trends in the lower trophic levels. In recent years, four volumes have summarized the research in Halifax Harbour (Nicholls, 1989a,b, 1991; Ducharme 2000), but there has been no explicit consideration of plankton distributions. Earlier, researchers at Dalhousie University (Riley, 1974; Lewis 1985) made useful contributions in their considerations of biological oceanography with respect to water quality in the habour, but scientific advances in the intervening years have led to the collection of a large volume of different measurements that are here reviewed. The aim of this paper is therefore to describe the biomass and physico-chemical environment of the plankton microbiota in Halifax Harbour, and then to speculate on whether the long-term annual trends are local to the Harbour or are indicative of larger-scale changes.

Planktonic microbiota

The contemporary view of plankton foodwebs is now solidly grounded on a quarter century of new discoveries of microbial groups and new insights into trophic structures and functions (Kirchman, 2000). The planktonic microbiota span 4 orders of magnitude in size by cell length: they are the femtoplankton (0.02-0.2 μm), the picoplankton (0.2-2 μm), the nanoplankton (2-20 μm) and the microplankton (20-200 μm)

A recent overview of marine microbes has been published by Sherr and Sherr (2000), from which we may extract the following brief summary. The femtoplankton are the viruses. Here, we are not concerned with human and animal pathogenic enteroviruses. Instead, we focus on the large number of virioplankters infecting other plankton - largely bacterioplankton, and to a lesser degree phytoplankton. The picoplankton are a diverse assemblage comprising members from all 3 domains of life: Bacteria, Eukarya and Archaea. In the Bacteria, the dominant members are the heterotrophic prokaryotes and the photoautotrophic cyanobacteria. In the Eukarya, the members include picoalgae and picoheterotrophic flagellates. With exception, very little is presently known about Archaea in surface waters of temperate coastal waters. The nanoplankton include photosynthetic algae, heterotrophic flagellated protists such as chrysomonads, choanoflagellates, as well as mixotrophic forms of prymnesiophytes and prasinophytes. The microplankton include photosynthetic algae, and microzooplankton such as phagotrophic dinoflagellates and heterotrophic ciliated protists typified by tintinnids. A microplankter of special note is the ciliate *Mesodinium rubrum*, which is photosynthetic by virtue of its chloroplasts "robbed" from cryptophyte algae. This cell chimaera occasionally forms a red-coloured bloom in Bedford Basin.

Earlier descriptions of plankton in Halifax Harbour were predicated on the traditional herbivorous food chain in which diatoms and dinoflagellates are consumed by copepods, which in turn are eaten by larger consumers. It is now evident that marine plankton communities are generally not structured this way, and that the herbivorous food chain is actually one end-member of a continuum of trophic pathways (Legendre and Rassoulzadegan, 1995). Clearly, efforts to monitor long-term change in plankton communities that rely solely on information gathered from nets with large mesh openings are a relic of an earlier era in oceanography and doomed to uncertainty. Statements about the state of the ecosystem cannot be regarded as conclusive without consideration of the significant biomass and turnover of the microbiota.

It is noteworthy that the longest and arguably the best monitoring program in biological oceanography (Continuous Plankton Recorder Survey) has embarked on an effort to enumerate picophytoplankters, bacteria and viruses collected by a towed water sampler in addition to the net-plankton collected by the conventional gauze filtering system (SAHFOS 1999 Annual Report). On the Scotian Shelf, evidence from the CPR surveys indicate that net-phytoplankton (diatoms and dinoflagellates) were higher in the 1990's than in the 1960's and early 1970's (www.meds-sdmm.dfo-mpo.gc.ca/alphapro/zmp/plankton/cpr/scotian_shelf_cpr_e.htm). We have also embarked on a program to monitor the picophytoplankton, bacteria and viruses in these waters.

Annual plankton cycle

The annual cycle of phytoplankton biomass in temperate coastal waters has been documented since the earliest days of biological oceanography, and understood to be regulated by seasonal changes in water column mixing and stratification. Recently, we described the annually recurring events in Bedford Basin from weekly observations made over a 9 year duration (Li and Dickie, 2001).

In Bedford Basin , the cycle is set into motion at week 7 or 8 of the year. This is the time of minimum temperature after which daily solar radiation increases and surface warming begins to stabilise the water column which has been intensely mixed over the winter. These factors initiate the spring bloom of phytoplankton, which may sometimes begin earlier in Bedford Basin than offshore. At this time, nutrients decrease rapidly from their winter maxima to supply the growth of phytoplankton biomass (chlorophyll). This biomass reaches a peak at week 11 or 12 during the spring equinox.

From the spring equinox to the summer solstice (week 25 or 26), there is intense microbial growth, even as bulk chlorophyll decreases. The total number of phytoplankton cells increases, in small part due to cryptophytes, and in spite of a decrease in the cyanobacterium *Synehcococcus*. The picophytoplankton make up an increasingly larger percentage of total chlorophyll biomass (from a low of 15% to a high of 55%) during these weeks. The heterotrophic bacteria and viruses increase at sustained rates to respective maxima at the summer solstice. As well, microzooplankton biovolume increases. Through this period, there is an increased flux of regenerated nutrients, but this is largely balanced by the flux of uptake as spring progresses.

The summer, from the solstice to the autumn equinox (week 37 or 38) is perhaps the most interesting part of the year from a microbial point of view. The thermocline is fully formed and surface nitrate approaches undetectable limits, but ammonium is available as a result of microbial regeneration. Both bacteria and viruses fall off slightly from their maxima but remain relatively abundant throughout the summer. This is also the time of year when the ratio of viruses to bacteria is highest. The weekly average concentration of chlorophyll increases, building up to a peak (the fall bloom) in September. Throughout the summer, primary production is at levels almost as high as in the spring. Short-lived blooms of dinoflagellates are not unusual, but they do not recur with annual regularity. One such bloom in 1993 led to the highest value of chlorophyll recorded in this basin (109 mg m^{-3}). Summer culminates in the autumn equinox when water temperature is at its highest average value for the year. This is the time of maximum phytoplankton abundance, and accounts for the peak of the fall bloom as measured by bulk chlorophyll . It is also the time of maximum tintinnid abundance, maximum microzooplankton biovolume, and maximum microbial biomass as measured by particulate ATP.

From the autumn equinox to the winter solstice, the stratification of the water column begins to be eroded by lower air temperatures and stronger winds, bringing nutrients to the surface. However, increased discharge from the Sackville River and lower surface salinity retard the destratification to some extent. Before the solar radiation becomes too low, there is an opportunity for moderate phytoplankton renewal; for example as a short-lived bloom of the dinoflagellate *Ceratium longipes*. After the winter solstice, the water column is completed destratified and the microbial populations, excepting *Synechococcus*, reach their annual minima.

In summary, the surface waters of Bedford Basin exhibit general features common to many coastal plankton systems dominated by phytoplankton biomass and production. A major bloom of phytoplankton biomass in spring is fueled by nitrate, a lower but sustained level of phytoplankton biomass in summer is fueled by recycling activities of bacteria and viruses, a secondary bloom of phytoplankton biomass develops in autumn, and a return to lowest community biomass occurs in winter.

Spatial gradients

The physical setting of the Halifax inlet system (Fig. 1) has been well-described in previous volumes (Nicholls, 1989a,b, 1991;

Ducharme 2000). Very briefly, the innermost part of the system is Bedford Basin, which is 6 km long, 17 square km in area, and 70 m in maximum depth. Seaward of the Basin is a shallow sill marking the inner portion of Halifax Harbour, which is 8 km long, 0.5 to 1.5 km wide, and only 20 m in depth. The outer portion of the Harbour is also about 6 km long, but much wider at 7 km, and 20 to 30 m deep. A line drawn from Chebucto Head to Devil's Island is usually taken to demarcate Halifax Harbour from the continental shelf.

The physical oceanography of the inlet system is also quite well-understood (Ruddick, 1985a,b). Essentially, Halifax Harbour is an estuary in which the mixing, dispersion and flushing of seawater are affected by freshwater discharge from the Sackville River entering the head of the Basin, by tidal currents, by winds, and by occasional intrusions of dense shelf water forced by upwelling.

A transect of 11 stations extending from the head of the inlet at Bedford Bay to the continental shelf beyond Chebucto Head (Fig. 1), sampled at 1,5 and 10 m depths, reveals the zonation of the 3 areas: Bedford Basin, inner harbour, and outer harbour. On October 1, 1996, temperature, freshwater content, inorganic nutrients (nitrate, phosphate, silicate), dissolved organic carbon, particulate organic carbon and particulate organic nitrogen were all highest in Bedford Basin (Fig 2). The inner and outer harbours were similar to each other in their cooler and saltier waters, but the outer harbour was much lower in nutrients and slightly lower in POC and PON (Fig. 2).

The zonation was also evident in phytoplankton composition (Fig. 3) and microbial abundance (Fig. 4). The general decrease of total phytoplankton biomass (Chl *a*) from inshore to offshore was reflected to varying degrees by diatoms (fucoxanthin), dinoflagellates (peridinin), cryptophytes (alloxanthin) and cyanobacteria (zeaxanthin). However, the "green" algae (Chl *b*) and especially the prymenesiophytes (19'-hexanoyloxyfucoxanthin) were more favoured offshore than inshore (Fig. 3). Presumably, these latter groups are the taxa comprising many of the picophytoplankters and nanophytoplankters whose total abundance increased from inshore to offshore (Fig. 4). Bacteria were distributed fairly uniform across the transect, except perhaps at Georges Island where they were not only most abundant, but also appeared to have a larger genome (Fig. 4). Viruses were more abundant in Bedford Basin than in the inner and outer harbours (Fig. 4).

Although the dataset for October 1, 1996 has been chosen to illustrate the inshore-offshore gradients, it is necessary to note that the conditions on this week in Bedford Basin were a departure from their long-term climatological averages. In particular, the temperature and nutrient concentrations were significantly higher from weeks number 37 to 40 in 1996 than the long-term averages. In other words, the gradients we display for week 40 in 1996 were not typical for the average week 40. It will be pointed out later that the average conditions in Bedford Basin are the same as on the adjacent continental shelf areas.

Long-term trends

Since late 1991, weekly observations have been made at the Compass Buoy station in Bedford Basin. This monitoring program provides a unique dataset to examine plankton changes at weekly, monthly, seasonal and annual scales (www.mar.dfo-mpo.gc.ca/science/ocean/BedfordBasin/BedfordBasin.htm). For example, the time series (Fig. 5) has been used to compute the weekly averages on which the earlier description of annual plankton cycles was based (Li and Dickie, 2001).

In this section, we examine the long-term trends by considering data averaged at the annual time scale. Generation times of microbial plankton are, of course, much shorter and the community undergoes many successional events over the period of a year. However, the cycle of seasonal change returns the community to a state more or less similar to that from which it started 12 months previously. The question we pose is whether all the events that occur over a 12 month period, taken together, lead to a systematic change in the net state as the years go by.

Data prior to 1992 were extracted from a collection of 11 technical reports referenced in Li et al. (1998). Measurements of water temperature, nutrients and chlorophyll were available for a number of years back to 1967, but the record is not continuous (Fig. 6). The data give an impression that in the 1990's, the winters have become warmer, and that the concentrations of nitrate and phosphate have become greater (Fig. 6).

The computed annual average temperatures indicate that the water has warmed a remarkable 2°C over 33 years (Fig. 7). On an annual average basis, nutrients and chlorophyll, however, do not display any convincing, systematic trends (Fig. 7). In recent years, nitrate, phosphate and chlorophyll appear higher, while silicate appears lower than 3 decades ago - but these trends, with the exception of phosphate, do not satisfy the generally accepted criterion for statistical significance. On the other hand, the nutrient trends, weak though they may be, occur in opposite fashion for silicate versus nitrate and phosphate. For this reason, there is a downward trend in the ratios of silicate:nitrate and silicate:phosphate.

In other coastal waters, such as the Irish Sea, the Mississippi River, the Bay of Brest and the German Bight, the Si:N ratio has also shown decadal-scale decreases (Cloern, 2001). Since silicate is required as a macronutrient only by diatoms, other phytoplankters are at a competitive advantage when nutrient ratios shift towards silicate limitation. In the German Bight from 1962 to 1984, long-term reductions in the silicate ratios were accompanied by increases in phytoflagellates and decreases in diatoms. In Bedford Basin, full-year records for floristic composition are available only for recent periods. From 1993 to 2000, there has been a substantial increase in the abundance of nanophytoplankters as well as the picoplankter *Synechococcus* (Fig. 7); unfortunately, the information for diatom abundance is yet unavailable. At present, it is not possible to say whether the recent apparent increase in non-diatom phytoplankters is a long-term trend; and if so, whether it is a response to increased temperature, to altered nutrient ratios or to other factors.

The abundance of heterotrophic bacteria in Bedford Basin appears to have remained invariant at an annual average value of 2 million cells per mL from 1992 to 2000 (Fig. 7). A global survey of annual average bacterial abundance has demonstrated that 79% of its variance in temperate and polar waters can be explained by annual average temperature (Li, 1998). The abundance of bacteria in Bedford Basin is almost exactly that which is predicted by this relationship

Bedford Basin and the Scotian Shelf

Bedford Basin is connected to the adjacent continental shelf through a sill and a long channel. The exchange of shelf and inshore water, largely caused by alongshore winds driving Ekman transport, exerts strong control of the nutrient and chlorophyll regimes in the Basin. At a certain time scale, Bedford Basin loses its autonomy as an independent ecological unit because external physical forces dominate the intrinsic biological dynamics (Lewis and Platt, 1982). From considerations of physiography and water exchange at the inlet mouth, it has been estimated that the length of time required to flush the upper layers of Bedford Basin may typically be as few as 3 to 5 days (Lewis and Platt, 1982), or may be susbtantially longer (Ruddick, 1985a,b). At shorter time scales, aperiodic events occur in which local biological signals may override general seasonal patterns. These include exceptional events of red-water discolouration attributed to the dinoflagellates *Gonyaulax digitale* and *Dinophysis norvegica*.

At the time scale of one week, the computed climatologies in Bedford Basin may in fact be reasonable exemplars of the adjacent shelf (Fig. 8). Indeed, weekly average temperatures and nutrient concentrations in Bedford Basin might be used to interpolate monthly average values on the central Scotian Shelf, which have been published by Petrie et al. (1996, 1999). The coupling of Bedford Basin to the adjacent continental shelf at longer time scales suggests that there may be close similarities in the annual sequence of recurring biological events in these areas. To date, measurements of microbiota on the Scotian Shelf in the Atlantic Zone Monitoring Program confirm a similar annual cycle of microbial events, such as the emergence of picophytoplankton in the autumn (Fig. 9).

Conclusions

Since 1967, the surface waters of Bedford Basin have increased in temperature by about 2°C on an annual average basis. During this period, there appears to have been a weak shift in the ratios of the dissolved inorganic macronutrients favouring nitrate and phosphate over silicate. Although total phytoplankton biomass as indexed by chlorophyll *a* appears not to have changed systematically, there has been an increase in the number of smaller cells (nano- and picophytoplankton) since at least 1993. At the monthly and seasonal scales, Bedford Basin and the adjacent area on the Scotian Shelf are similar with respect to temperature,nutrient concentrations and microbial standing stocks. It remains to be seen whether the long-term trends in these two areas are concordant.

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References

Cloern J.E. 2001. Our evolving conceptual model of the coastal eutrophication problem. Marine Ecology Progress Series 210:223-253.

Ducharme A. (Ed.) 2000. Preserving the environment of the Halifax Harbour. Fisheries and Oceans Canada and Halifax Regional Municipality Workshop #1, March 2000.

Kirchman D.L. (Ed.) 2000. Microbial ecology of the oceans. Wiley-Liss, New York. 542pp.

Legendre L. and Rassoulzadegan F. 1995. Plankton and nutrient dynamics in marine waters. Ophelia 41:153-172.

Lewis M.R. 1985. Biological oceanographic aspects of sewage addition to Halifax inlet. Halifax inlet water quality study. Phase I: Data review. Metropolitan Area Planning Commission of Halifax, Dartmouth, Bedford and Halifax county. 21pp.

Lewis M.R. and Platt T. 1982. Scales of variability in estuarine ecosystems. In: Kennedy, V.S. (Ed.) Estuarine comparisons. New York: Academic Press. p 3-20.

Li W.K.W. 1998. Annual average abundance of heterotrophic bacteria and *Synechococcus* in surface ocean waters. Limnology and Oceanography 43:1746-1753.

Li W.K.W. and Dickie P.M. 2001. Monitoring phytoplankton, bacterioplankton and virioplankton in a coastal inlet (Bedford Basin) by flow cytometry. Cytometry: submitted.

Li W.K.W., Dickie P.M. and Spry J.A. 1998. Plankton monitoring programme in the Bedford Basin, 1991-1997. Canadian Data Report of Fisheries and Aquatic Sciences 1036: vii+342pp.

Mann K.H. 2000. The living estuary. In: Preserving the environment of the Halifax Harbour. Ducharme A. (Ed.), Fisheries and Oceans Canada and Halifax Regional Municipality Workshop #1.

Nicholls H.B. (Ed.) 1989a. Investigations of marine environmental quality in Halifax Harbour. Canadian Technical Report of Fisheries and Aquatic Sciences 1693: v+83pp.

Nicholls H.B. (Ed.) 1989b. First Halifax inlet research workshop. Bedford Institute of Oceanography, Dartmouth, November 1989, ii+33pp.

Nicholls H.B. (Ed.) 1991. Second Halifax inlet research workshop. Bedford Institute of Oceanography, Dartmouth, February 1991, ii+47pp.

Petrie B., Drinkwater K., Gregory D., Pettipas R. and Sandström A. 1996. Temperature and salinity atlas for the Scotian Shelf and the Gulf of Maine. Canadian Technical Report of Hydrography and Ocean Sciences 171: v+398pp.

Petrie B., Yeats P. and Strain P. 1999. Nitrate, silicate and phosphate atlas for the Scotian Shelf and the Gulf of Maine. Canadian Technical Report of Hydrography and Ocean Sciences 203: vii+96pp.

Riley G.A. 1974. Oceanography of the Halifax inlet in relation to problems of sewage disposal. Nova Scotia Department of the Environment Report. Prepared under the auspices of Institute of Environmental Studies, Dalhousie University, with the help of A. Pease, D. Stucchi, and R. Loucks. 44pp.

Ruddick B. 1985a. Review of physical oceanography of Halifax Harbour. Halifax inlet water quality study. Phase I: Data review. Metropolitan Area Planning Commission of Halifax, Dartmouth, Bedford and Halifax county. 13pp.

Ruddick B. 1985b. Relevant physical oceanography of Halifax Harbour. Halifax inlet water quality study. Phase II: Appendices. Metropolitan Area Planning Commission of Halifax, Dartmouth, Bedford and Halifax county. 60pp.

Sherr E. and Sherr B. 2000. Marine microbes: an overview. In: Microbial ecology of the oceans. Kirchman D.L. (Ed.) Wiley-Liss, New York. pp 13-46.

Figure 1 Sampling stations along Halifax Harbour transect: October 1, 1996

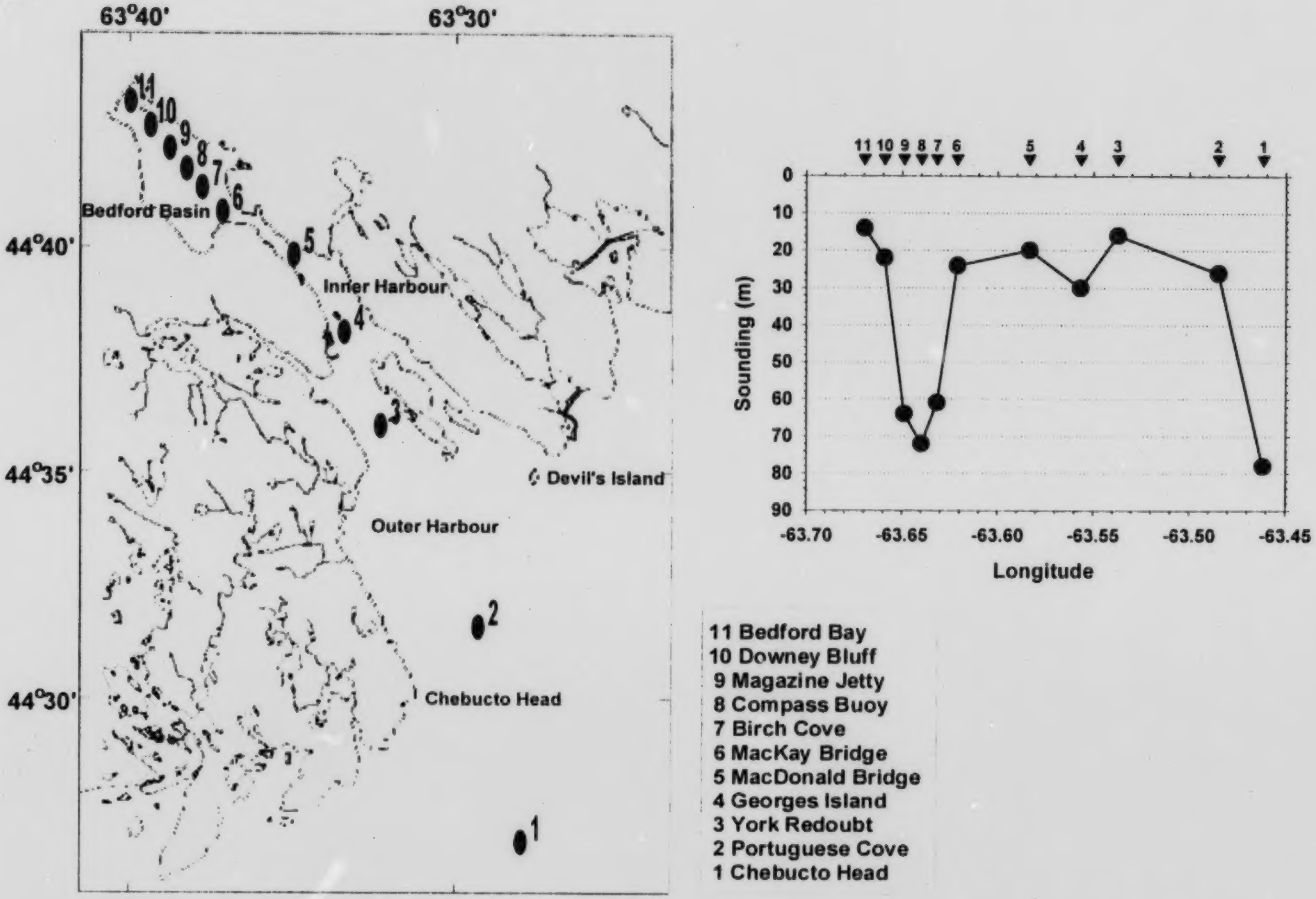


Figure 2 Physico-chemical variables along Halifax Harbour transect: October 1, 1996

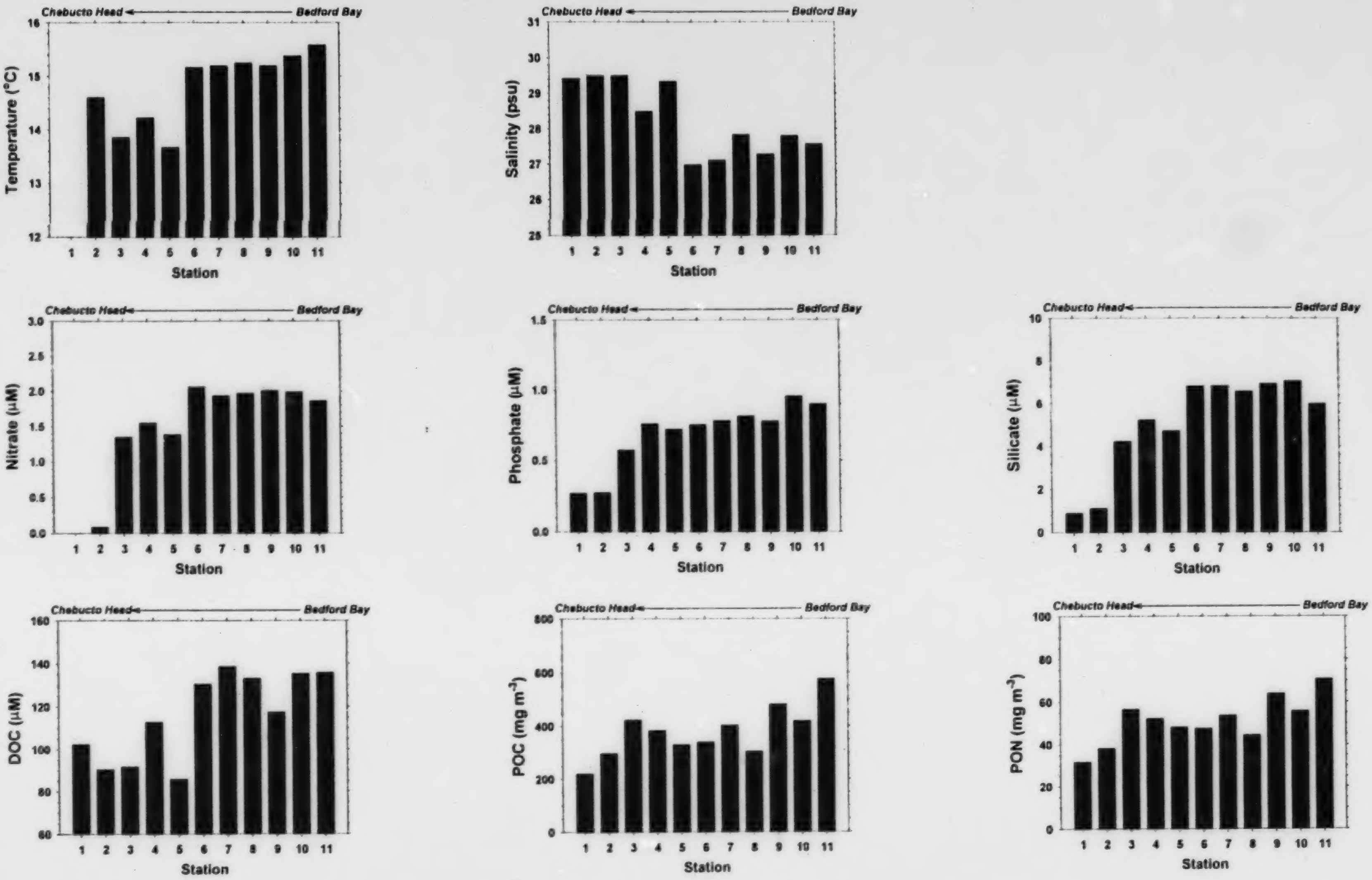


Figure 3 Photosynthetic pigments along Halifax Harbour transect: October 1, 1996

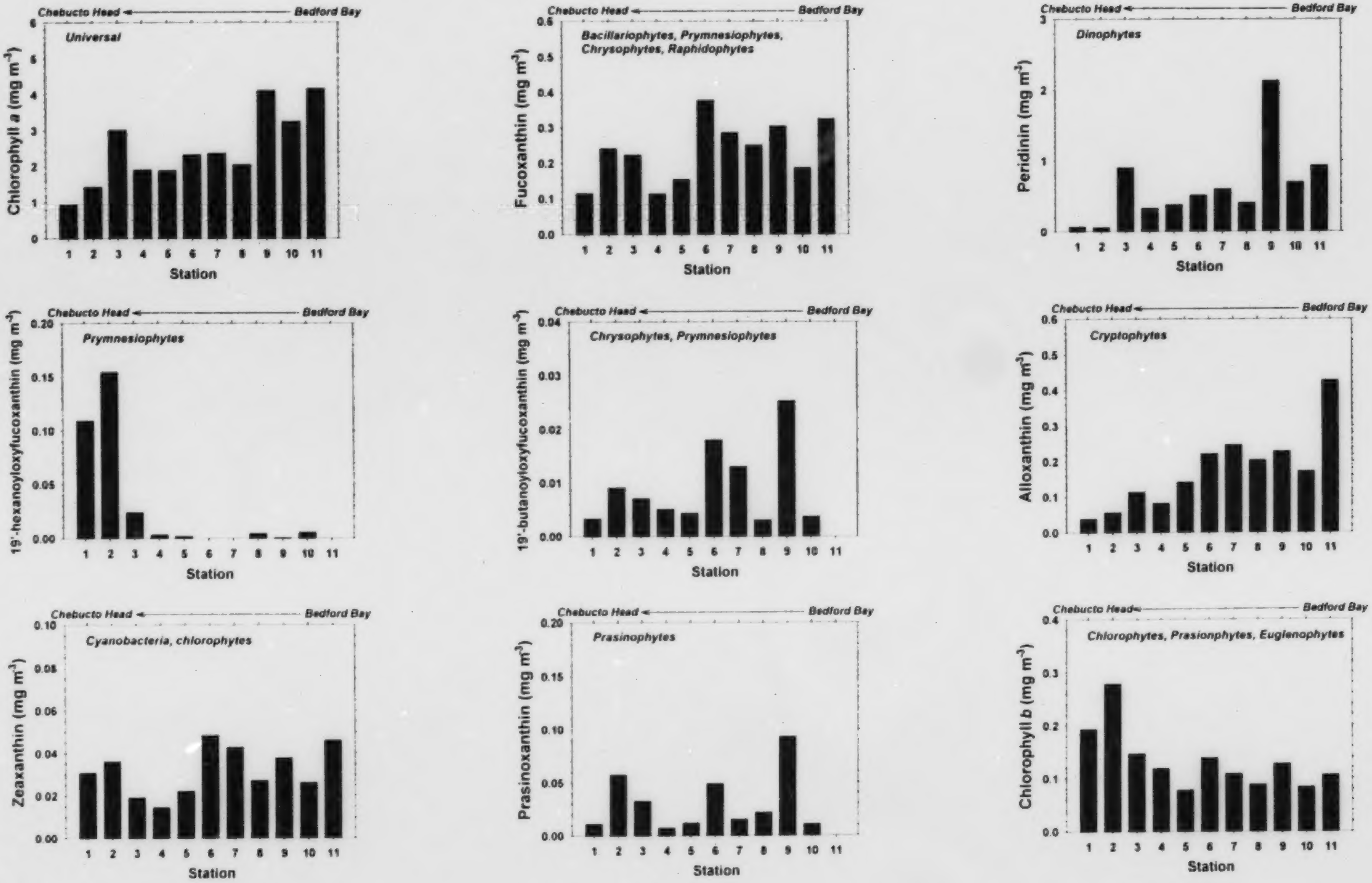


Figure 4 Microbial plankton abundance and cell properties a long Halifax Harbour transect: October 1, 1996

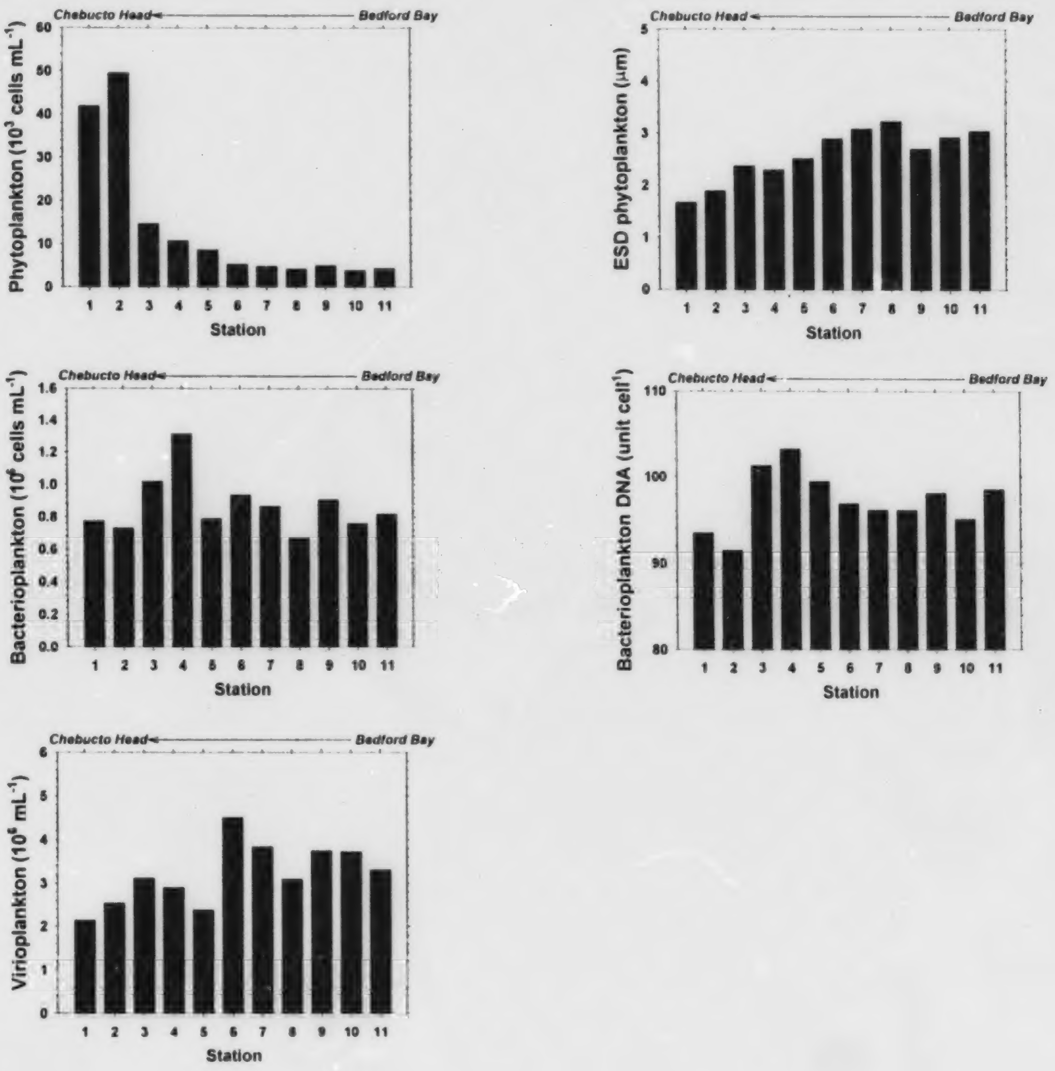


Figure 5 Time series of temperature amd microbiota at the Compass Buoy, 1992-2000.

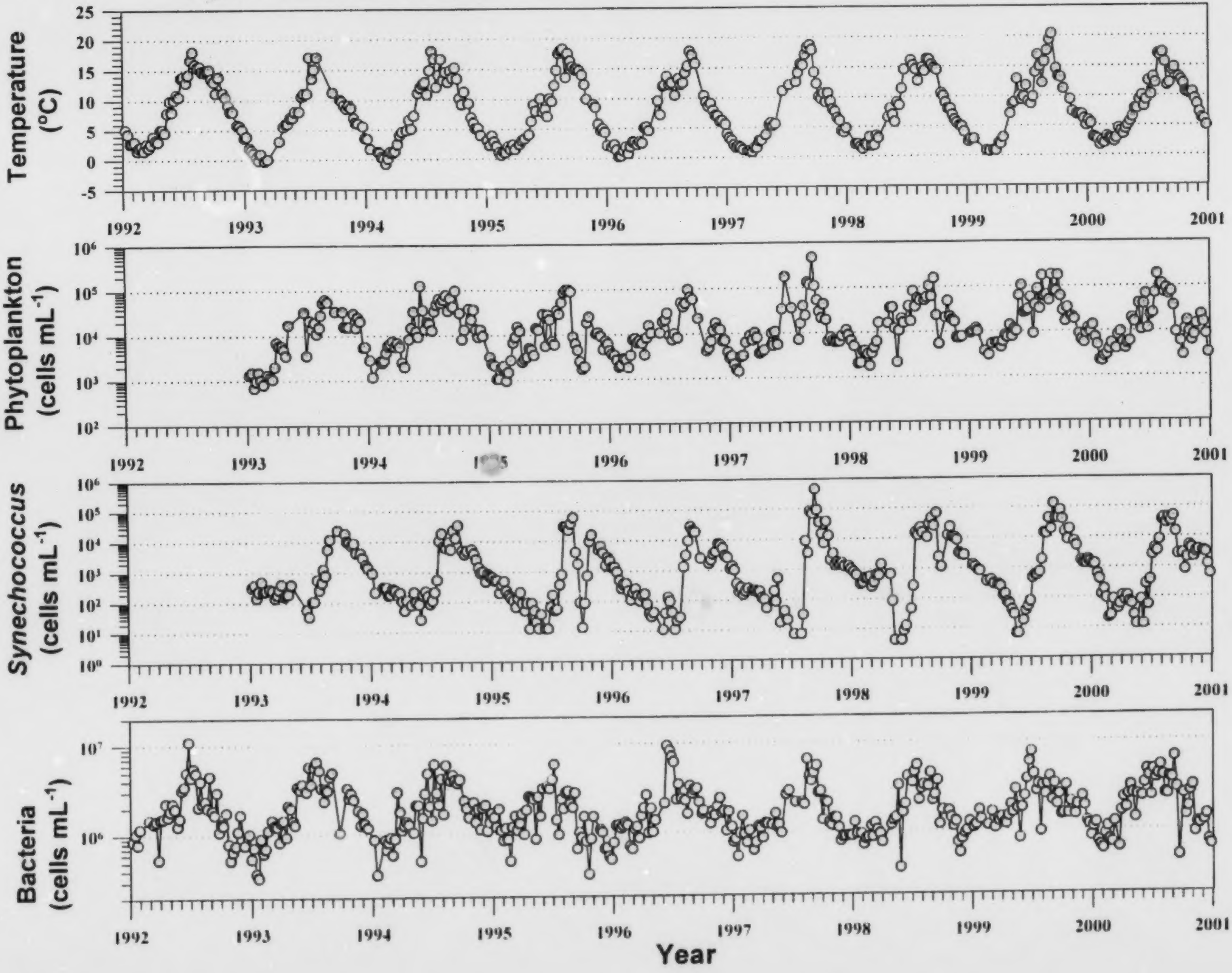
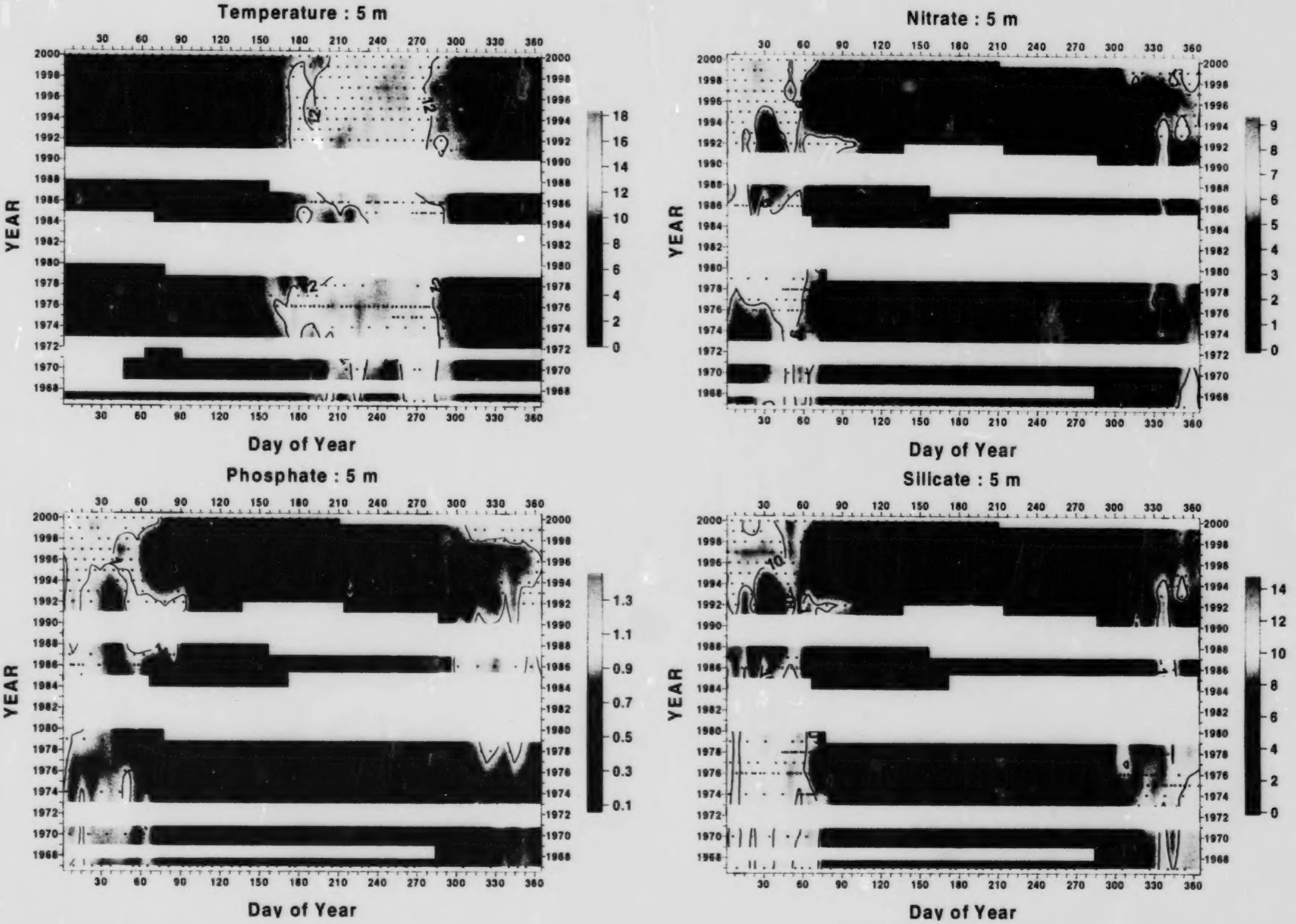


Figure 6 Time series of temperature and nutrients at the Compass Buoy, 1967-2000



Temperature : 5 m

Nitrate : 5 m

Phosphate : 5 m

Silicate : 5 m

Figure 7 Annual averages of temperature, nutrients, chlorophyll and microbiota at the Compass Buoy, 1967-2000

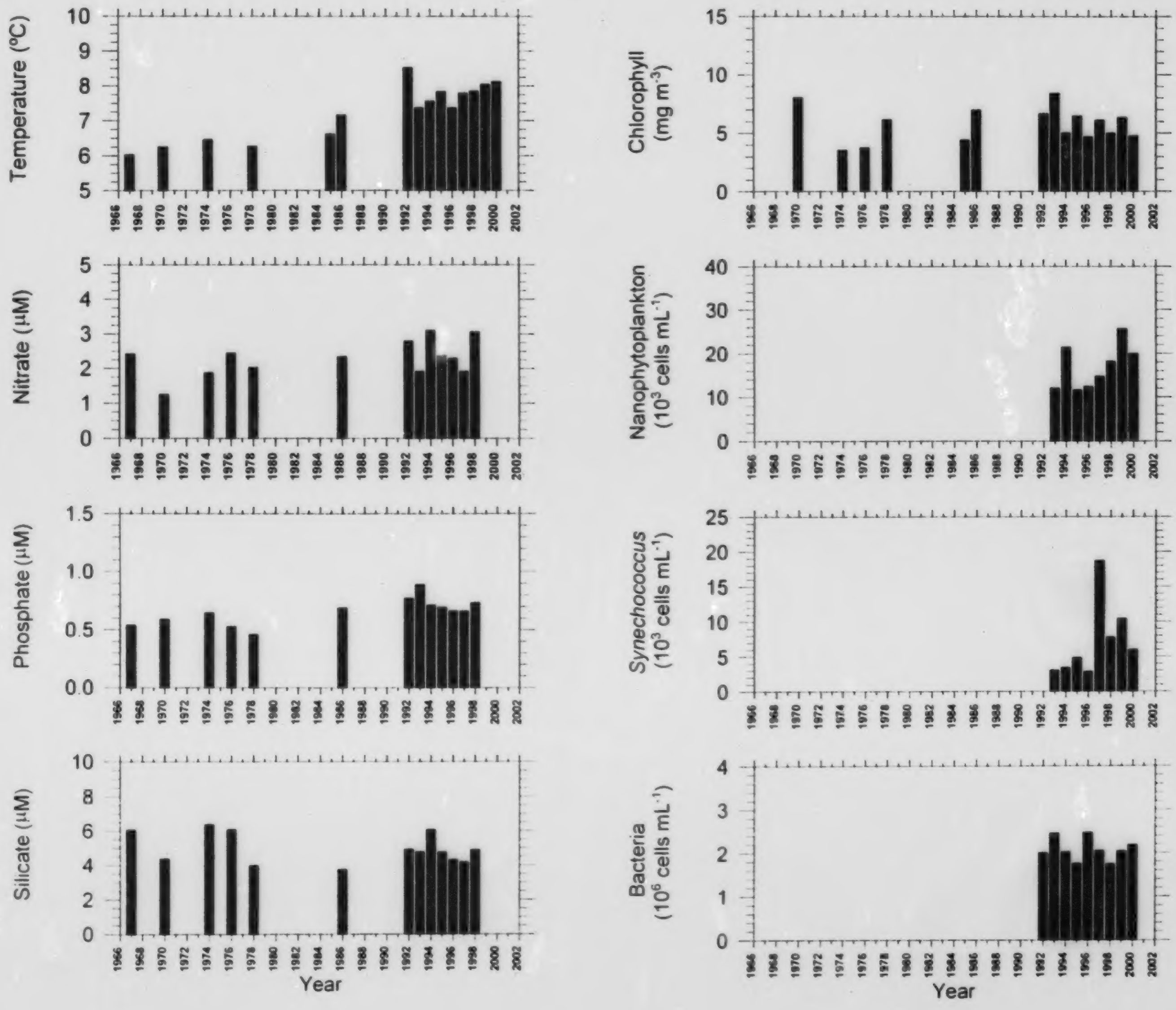


Figure 8 Nutrients and their ratios: weekly averages in Bedford Basin compared with monthly averages on the central Scotian Shelf

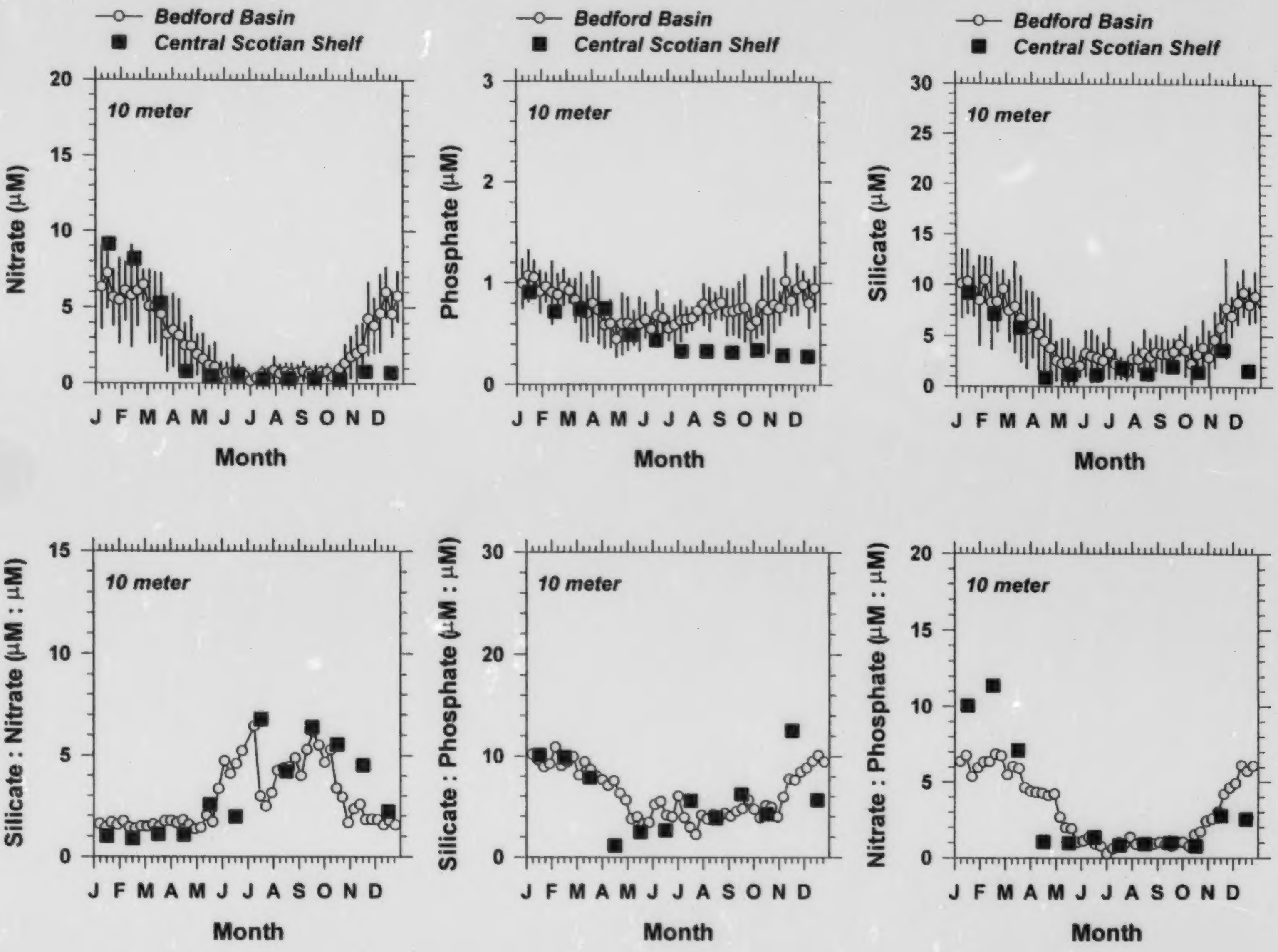
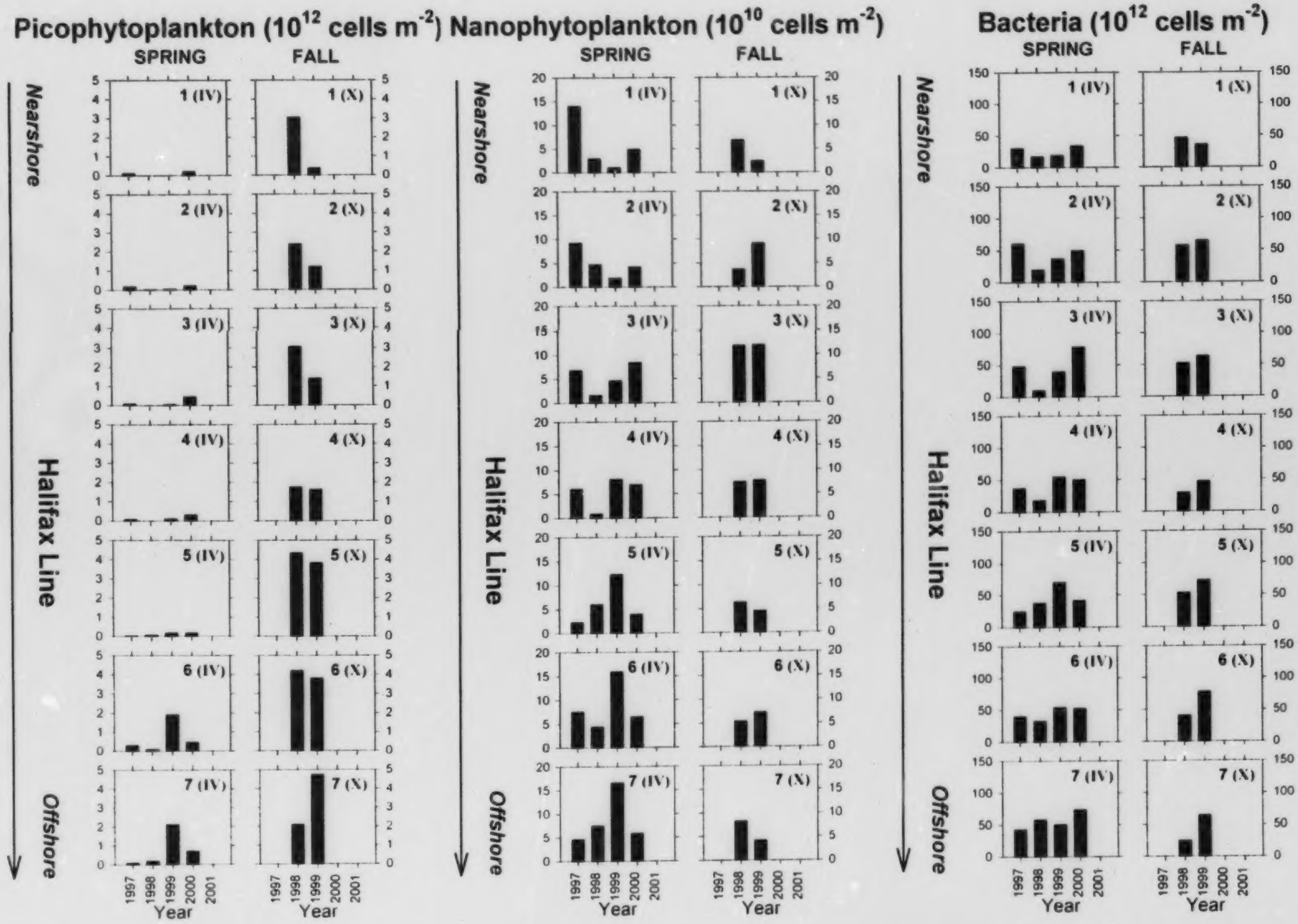


Figure 9 Microbial standing stocks along the "Halifax Line" stations 1 to 7, spring (IV) and fall (X) 1997-2000



Halifax Harbour: What Do We Know and What Do We Need to Know?

Ken Mann

Introduction

This paper summarises what we know about the ecology of Halifax Harbour, as presented at the first and second workshops "Preserving the Environment of Halifax Harbour". The material is presented in note form.

The harbour as an estuary

From the patterns of water circulation and the presence of all the essential elements of the flora and fauna, we know that in spite of all the man-made changes, Halifax harbour still functions as an estuary. The inflow of fresh water drives a current seaward at the surface, while near the bottom, salt water moves into the estuary at the mouth to compensate for the outward flow at the surface. Estuaries act as traps for nutrient material entering with the rivers and with the salt water near the bottom. They are therefore more productive than the open sea, and in the past Halifax harbour was noted for the abundance of fish and shellfish.

The physical environment

The geological history, surficial and bedrock geology are well known. During the growth of the Halifax-Dartmouth-Bedford community there has been extensive infilling of the margins of the harbour, with corresponding loss of shallow-water habitat. The watersheds of the Sackville River and other freshwater sources have been heavily modified by urban development. Recent infilling has been by the use of pyritic slate removed during other developments. Studies are in progress to determine whether this material has any deleterious effect on the marine environment.

The biological community

The expected groups of plants and animals are present in the harbour, but in lesser quantities than in earlier times. We believe that this is the result of the loss of shallow water habitat and the contamination of the harbour with silt, sewage, metals and organic substances. Of the marine mammals, we see harbour seals, porpoise, dolphins and occasional right whales. A good variety of groundfish and pelagic species are harvested in the outer harbour. Pollock, herring, mackerel and smelt are fished for bait in the inner harbour. Salmon, sea trout, gasperau and eels pass through the harbour on their way to the rivers. A good variety and abundance of aquatic birds occur in the outer harbour.

Lobsters are fished extensively, especially around McNab's Island and seaward from there. There is limited fishing in the Northwest Arm and Bedford Basin. Clams and mussels are abundant throughout the harbour, but are closed to harvesting on account of faecal coliform contamination.

Contaminants

The harbour receives almost 200 million litres of raw sewage per day, from 26 outfalls, all situated seaward of the narrows. Plans for treatment of the sewage are being developed. There is a sewage treatment plant near the landward end of Bedford Basin. The effluent is rich in plant nutrients such as nitrate and phosphate.

Reported oil spills averaged over 80 per year in the period 1994-1999, but the rate of occurrence is declining.

An unknown amount of leachate enters the harbour from the old city dump near the narrows.

The effect of contamination

Sewage effluent. Untreated sewage effluent contains organic solids, dissolved nutrients and contaminants. Organic solids settle on the bottom and consume oxygen from the water. The deep part of Bedford Basin has low oxygen content for part of each year. This limits the number of species of invertebrates and fish that can live there. Dissolved nutrients stimulate the growth of phytoplankton and bacteria. If more are produced than the animals can consume, they settle on the bottom and add to the oxygen demand. Organic solids smother seaweeds and seagrasses in shallow water, leading to loss of fish habitat and reduction of fish and invertebrate production.

Contamination with metals. The estimated annual input of metals to the harbour includes 36 tonnes of zinc and 34 tonnes of lead, with lesser amounts of copper and other metals. It is estimated that the upper 2cm of sediment in the harbour contain 208 tonnes of zinc and 200 tonnes of lead, so the full depth of sediment contains much greater amounts. It is believed that only 10-20% of the input is by way of the sewers, the remainder coming from land runoff, and from sources within the harbour, such as seepage from the old dump and wreckage of ships on the sea floor.

Organic contaminants. The presence of organic contaminants is known from the study of the tissues of invertebrates and fish. A large range of substances is found, but two of the most important are polycyclic aromatic hydrocarbons (PAHs), which occur in the tissues of mussels and polychlorinated biphenyls (PCBs) which are found particularly in the digestive glands of lobsters. The mussels show a seasonal rise and fall in PAH content. From 18 sites studied, many show low background levels, but some sites show a marked elevation of PAH content. Some PAH's are clearly associated with petroleum hydrocarbons. The harvesting of mussels is prohibited, but the prime reason is their contamination with faecal coliform bacteria.

Lobsters accumulate both PCBs and PAHs in their digestive glands. The levels do not exceed the allowable limits for human consumption. There is a decrease in concentration in lobsters taken along the gradient from the industrialised inner harbour to the mouth of the estuary.

What more do we need to know?

The priorities in collecting further scientific information depend on our objectives. For example, one may wish to halt or reverse the degradation of the estuarine system, or one may restrict the objective to trying to ensure that future developments do not further contribute to degradation.

To halt or reverse system degradation. To halt the degradation caused by sewage contamination, obviously we need sewage treatment. However, it is likely that the effluents of treatment plants will still contain plant nutrients such as nitrate and phosphate, and some organic solids. We need to know the expected composition of the effluents, in order to predict their effect on the plankton and on the bottom communities. We need to understand how the water circulation in the harbour will affect the distribution of material from the effluent pipes, and for this we need a good physical model of water movement. Such a model may exist, but it has not been presented in these workshops.

To halt the degradation caused by metal contamination, we need to consider both the materials entering the harbour on a daily basis and the accumulated material in the sediments. We need to know the details of the origins and pathways of the incoming metallic contaminants that are not in the sewage (about 80% of the total). For example, how much is in the leachate from the old city dump, and how much in the waters of the Sackville River? Obviously, a strong program to reduce contamination at source is needed, but if a significant proportion is leaching from the old dump, or from scrap metals on the harbour floor, special measures may be needed to contain it.

Sediments containing organic matter may be oxidised in the upper few millimetres, but deeper in the sediment conditions are likely to be anaerobic. Disturbance of sediments, for example by anchors, or by the turbulence created by ships' propellers, is likely to change the state of oxidation and may cause the release of metals bound in the sediments. We need much more information about these processes. Some have asked whether we should be aiming to remove contaminated sediments from the harbour. At present it seems that it would cause more harm than good, by releasing large quantities of contaminants. Furthermore, disposal of contaminated sediments would present a major problem. It may be that leaving the sediments in place, to slowly oxidise over time, with a gradual release of contaminants, is the best course of action.

Similar remarks apply to organic contaminants in the sediments. In addition to PAH's and PCB's, there is a long list of organic contaminants that have been identified. There is much work to be done in identifying the origins and fates of these substances. While reduction of contamination at source is obviously required, a deeper understanding of the processes leading to contamination of organisms in the harbour would facilitate the setting of priorities in the cleanup process.

To ensure that future developments do not cause further degradation. In any future development on the shores of the harbour, infilling should be kept to a minimum, since infilling reduces shallow water productivity and hence the productivity of the whole system. For any essential infilling, we need to know full details of the size and type of habitat that will be destroyed. We also need to know details of possible disturbance of the sediment during construction, because of the risk or releasing contaminants. Details are also needed of the nature of any infilling material, so that its possible interaction with the water and sediments can be investigated.

Interpretation of the facts

Although we know that Halifax harbour still functions as an estuary, its functioning has been impaired by man-made changes, with the result that the harbour is much less productive of fish and invertebrates than in former times. Specifically,

- Structures built by infilling have removed an estimated 40% of the habitat for seaweeds and seagrasses, with the accompanying loss of fish habitat and productivity
- Soil erosion in the basin of the Sackville River has led to the smothering of large areas of benthic habitat with silt
- Discharge of large volumes of untreated sewage has smothered large areas of seaweed and seagrass, causing loss of fish

habitat and productivity.

- The untreated sewage contains large quantities of faecal coliform bacteria, rendering the shellfish unfit to eat
- Organic and inorganic contaminants have entered the system with sewage, river runoff and leachate from the old city dump at Seaview Point. As a result, lobsters, shellfish and fish are contaminated with organic and inorganic substances to a level that is judged not injurious to human health, but which may affect the growth or reproduction of the organisms themselves.

Questions and Answers
Part 3

Question:
Annemarie/Bruce Hatcher, must we end up saying that there are no areas of the Harbour that can be saved or restored? Are there actually some areas virgin enough that we can protect them as is, just leave them alone?

Annemarie/Bruce Hatcher:
In our opinion there are araes which have been impacted by human interventions, but we should still try to clean as many of these up as is feasible. There are other areas which have been impacted little or not at all, and these should be protected through zoning, creation of parks, etc.

Question:
Mr. Li, is there any evidence from the bacterial time series you have shown us to suggest utrification of the Halifax Harbour or Bedford Basin?

Bill Li:
Not a far as the upper 20 m of the water column is concerned. However, I have not tabled any data from the bottom of either of these areas, and it here I think we must look in thr future.

Question:
Do the anoxic conditions noted in your data on the bottom of certain parts of Bedford Basin last all year, or are there periods when oxygen is present on the bottom in those areas?

Bill Li:
The simple answer is yes, there are periods of the year when oxygen is present in all parts of the bottom of the Basin.

Question:
Dr. Mann, do you think that making an inventory of habitat lost due to infilling should be part of the important goal of halting, and where possoble reversing, degradation of habitat in the harbour?

Ken Mann:
Yes, I think it makes sence to inventory what has happened in order to begin on improving the situation.

Part 4

Achievable Goals

Halifax Harbour Solutions
Project Update

Tony Blouin

- **State of the Harbour - Environmental Impacts**

There are currently over 40 separate untreated municipal sewer outfalls in Halifax Harbour, as well as a number of institutional and private outfalls. These introduce between 100 - 150 million liters / day of untreated wastewater into the harbour, consisting of sanitary sewage as well as stormwater runoff from those older areas of Halifax and Dartmouth which still have combined sewer systems. The result of this discharge has been contaminated sediments around the outfall locations, poor water quality, bacterial contamination, a shellfish harvesting closure through much of the harbour, and poor aesthetics along the waterfront areas.

- **Historical Background**

Communities around the harbour have contributed to a history of 250 years of untreated sewage disposal. Two treatment plants were built in the 1970's at Mill Cove in Bedford, and at Eastern Passage. The Mill Cove plant provides advanced secondary treatment for Bedford-Sackville, and discharges to Bedford Basin. The Eastern Passage plant provides primary treatment for Cole Harbour - Eastern Passage, discharging to the harbour. Since those plants were built, many plans have been advanced to complete the regional sewage treatment system, including proposals for a single regional plant at locations such as Sandwich Point, Point Pleasant, and McNab's Island. With municipal amalgamation in 1996, HRM Council identified action on a harbour project as one of the major priorities. HRM held a public Symposium in 1996 to solicit community input on how to proceed, and appointed the Solutions Advisory Committee in 1998 to provide detailed recommendations on outstanding issues. HRM issued a Request for Proposals (RFP) in 2000 to a short list of 3 consortia.

- **Harbour Solutions Project**

HRM has developed a concept plan for up to 4 plants, to be located at Halifax North (Barrington and Cornwallis), Halifax South (former VIA Rail maintenance facility), Dartmouth (Coast Guard station), and at Herring Cove (possibly Hospital Point). The plan calls for advanced primary treatment with UV disinfection, and diffusers designed to provide 1:50 minimum dilution of the treated effluent. A key component of the project will be biosolids management, to make some beneficial use of the organic material extracted during treatment.

- **Treatment Process**

The advanced primary treatment

process begins with a screening / grit removal stage, followed by a primary settling / floatation stage in which solids settle out and floatable materials are also removed. The advanced primary stage then adds a flocculant which causes finer particulates to clump together for enhanced settling. Such flocculants are also commonly used in the treatment of drinking water supplies, and are recovered from the process in the biosolids. The advanced primary process results in >70% particulate removal. The treated wastewater is subjected to UV disinfection prior to discharge. UV has been selected to avoid environmental problems with contaminants which may be created through disinfection processes involving materials such as chlorine. UV technology for wastewater disinfection has recently improved to the point where it has become suitable for advanced primary effluent.

- **Biosolids (Sludge) Management**

An important component of the project will be to manage the biosolids or sludge produced by the treatment process from the four new plants, as well as from the existing plants which HRM operates. Currently, sludge from these plants as well as from domestic septic systems is managed at a temporary lagoon facility at Aerotech Industrial Park. This facility will be replaced by a new facility which will treat the biosolids as a resource to produce a beneficial product. HRM has specified that no landfilling, incineration, or ocean disposal will be acceptable. Some type of composting process will be a likely solution, resulting in a product suited to appropriate uses (such as landscaping, silviculture, land reclamation), dependant on the levels of contaminants. Use of such materials is regulated by the province.

- **Source Controls**

Source control is the other major additional component of overall harbour wastewater management. HRM has produced a revised and updated Wastewater Discharge Bylaw, which places a more extensive set of controls on materials entering sewers from industrial, commercial and institutional sources. Earlier phases of the Source Control program identified major sources of such contaminants through identification and location of sources in key industrial categories, and in-pipe sampling of the sewer system to measure wastewater quality and trace sources. Subsequent phases of the program will seek to promote Best Management Practices for both businesses and homeowners, and will provide an enforcement effort.

- **Regulatory Requirements**

A joint federal/provincial environmental assessment of the McNab's Island single-plant plan was concluded in 1993, and that project was granted environmental approval. However, it did not proceed for economic reasons. The Harbour Solutions Project does require a federal environmental assessment, which will focus on differences in the environmental impacts of the present project as compared to the concept already assessed in 1993. No provincial assessment is required for the Harbour Solutions Project, although a number of provincial guidelines and standards do apply. In particular, a provincial permit is required to operate any treatment plant. Effluent limits have been established by the province for the new plants as follows: BOD_5 50 mg/l; Suspended Solids 40 mg/l; Fecal Coliforms 5000/100ml (Figure 1).

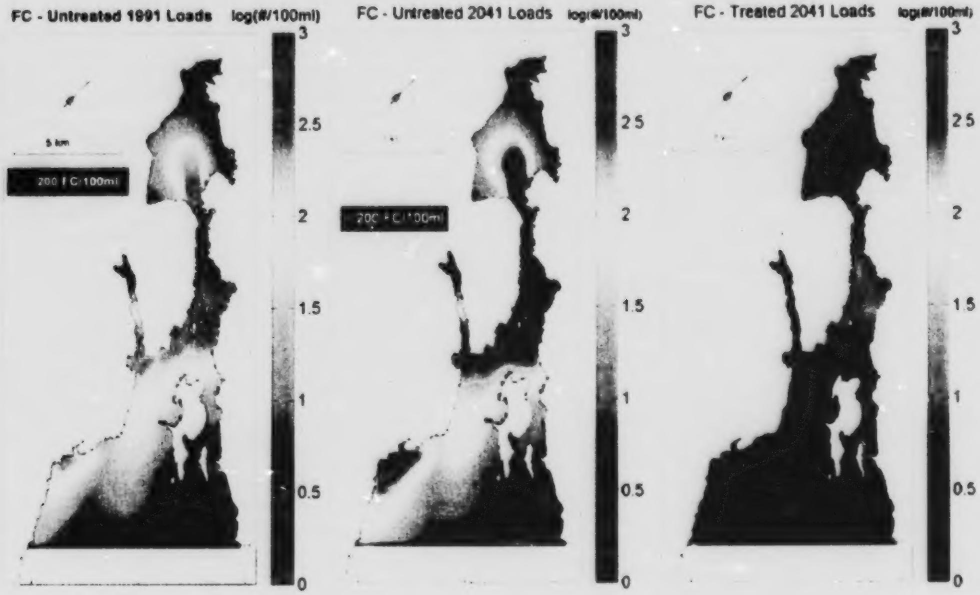
- **Impact Projections With & Without Treatment 2041**

Oceanographic modeling has been conducted to establish the assimilative capacity of the harbour in support of the effluent limits. Modeling projections of present and future water quality to 2041 (Fig.1) show that water quality would continue to deteriorate without treatment as a result of population growth. However, with the advanced primary / UV system proposed, water quality would be considerably improved as compared with the present situation, both for chemical as well as bacterial contaminants. With treatment, for example, the entire harbour should be well below the bacterial guideline limit for contact recreation.

- **Current Status of Project**

HRM issued an RFP in fall of 2000. Two proposals have been received, and are currently undergoing completeness, compliance and merit reviews. A PPP approach (design, build, operate) is possible, although HRM Council has not made a final decision on private vs public operation of the new plants. A recommendation to Council is expected in spring of 2001, with the possibility of construction commencement during 2001-2002. HRM has set a maximum 10 year time frame for system construction. The current capital cost estimate is $315,000,000 of which HRM has committed 2/3, as well as all of the operating costs. It is hoped that the remaining 1/3 capital cost will be jointly shared by the provincial and federal governments, although no commitments have yet been made.

Figure 1: Fecal Coliform (log#100ml)



The Hamilton Harbour Case: Lessons Learned

Victor Cairn

** This paper was not available in time for publication with the Proceedings

Eliminating Sources of Contaminants

Roger Percy

In last years workshop I addressed the problem of spills into Halifax Harbour and noted a 50 percent reduction in the number of spill reports between 1994 and 1999. This year I would like to focus instead on the elimination of contaminants from chronic pollution sources.

Municipal Wastewater Effluent

Harbour degradation resulting from municipal wastewater effluent is causing measurable environmental and economic damage in terms of loss of habitat and fishery potential. It also leads to higher dredging costs due to contaminant loadings and to real estate losses and a consequent loss of tax revenue.

We learned in the last workshop that there is an estimated 186 million litres of untreated sewage entering Halifax Harbour daily through seven major municipal outfalls situated in Halifax, Dartmouth and Herring Cove. This represents roughly 86 percent of the total municipal flow (Figure 1 and Table 1).

Municipal wastewater treatment systems are generally designed to accelerate the natural process of degradation by reducing a group of substances commonly found in sewage to acceptable levels that can then be assimilated by the receiving environment. Often a disinfectant is introduced as the final step in the treatment process to minimize the pathogenic organisms present in the effluent which ultimately protects human health and fishery resources.

Primary treatment involves physical treatment operations, screening and settling to remove settleables and floatable solids. Such treatment may be enhanced through the addition of chemicals to remove even more solids. Enhanced primary treatment plus disinfection is what is currently planned for HRM.

Secondary treatment is an additional biological process that uses a wide range of micro-organisms to convert the solid and dissolved materials in the wastewater into gases, water and more organisms which are then filtered or settled out of the stream. Chemicals may be added to enhance filtration or settling. Tertiary treatment is normally the removal of nutrients through chemical or physical means.

Sewage is more than human biological waste. On average you find more than 200 chemical substances in municipal wastewater effluents, including newer pollutants like metals, pharmaceuticals, PAH's, detergents, cleaning solvents, plasticizers and a host of other nasties.

Treatment systems are able to deal effectively with some of these contaminants, but certainly not all of them. Treatment processes are not capable of removing many of the commercial and industrial wastes that are often discharged to the collection system.

Studies have shown that primary treatment removes roughly 45 percent of conventional contaminants (BOD and total suspended solids), 47 percent of metals and only about 8.5 percent of total organic pollutants. Primary treatment also removes some nutrients achieving a 5-10 percent removal of nitrogen and 10-20 percent removal of phosphate.

It should be noted that secondary treatment is significantly more effective than primary treatment at removing most contaminants of concern.

The foregoing emphasizes the importance of source control in the elimination of contaminants entering the Harbour. The owners of the collection and treatment systems are encouraged to limit the introduction of non-biodegradable or toxic substances through prevention initiatives such as effective sewer use by-laws, pre-treatment of some industrial waste streams and education of the public. Metering of potable or industrial water and appropriate pricing can also be effective in reducing flows.

Environment Canada has recently embarked on the development of a National Municipal Wastewater Effluent Management Strategy in conjunction with provinces and other stakeholders. The first multilateral meeting was held in mid-January. This strategy will include all aspects of MWWE - pollution prevention, instruments (legislative, market-based, non-legislative), operations and maintenance, funding and resource optimization, scientific research and technology, communications and benchmarks for progress. Of particular federal concern is the matter of control instruments to meet legal obligations under CEPA and the Fisheries Act. This effort will help to guide HRM and other municipalities towards eliminating input of contaminants to our waterways.

Other Pollution Prevention Initiatives

At this stage I would like to very briefly touch on just a few of the many worthwhile pollution prevention activities that have recently been taken to further reduce contaminant input to the Harbour.

Ship Repair/Cleaning Operations:

Problems have been identified relative to contaminants entering the Harbour from ship repair facilities. These included copper slag used in sandblasting, contaminated paint chips and tributyl tin.

Approximately three years ago, leading by example, the government required federal operations to institute total containment and treatment/recovery of wastes at their facilities (Figures 2 and 3). Since that time the private sector has been provided with documentation on appropriate pollution prevention and state of the art control practices including the types of paints that are of concern and the precautions necessary to ensure that materials don't reach the marine environment. Legal action has been taken where voluntary compliance has not been forthcoming.

In a related recent initiative in November, 2000 an evaluation of the practice of polishing ships hulls to remove algal growth while they are moored in the Harbour was undertaken. This study clearly established that such practices lead to the release of contaminants well in excess of the Canadian Council of Ministers of the Environment (CCME) standards (Figure 4). As a result local diving companies, known to do this type of work, have been notified and advised that this is not an acceptable procedure without some form of containment and recovery.

Bringing Industry On Side:

The Eco Efficiency Centre at the Burnside Industrial Park provides strategic and technical information to assist businesses in reducing wastes, use of energy, and substitution of toxic chemicals by non-toxic alternatives.

In 1999 following some dramatic Harbour pollution incidents (Figure 5), Environment Canada in concert with the Nova Scotia Printing Industry Association and the Provincial Environment Department, undertook a project to assist the printing and graphics industry to reduce operating costs using pollution prevention practices. A manual was prepared which provided information to enable the industry to minimize use of toxics and divert wastes previously destined for the sewer system.

Reducing Contamination During Infilling:

During Phase 2 of the Bedford Basin infilling project shown here (Figure 6), rock material, with a potential to become acidic, is placed below the low water mark. Marine water inhibits the chemical and bacteriological process necessary for acidification to occur.

Standard rock fill is used to bring the site up to grade for future development purposes. Previously, acid generating rock was deposited in the watershed above the high water mark where leachate could readily migrate to the marine environment. This represents a win-win situation that reduces environmental impacts while providing a solution to the disposal of large quantities of waste generated during construction of the natural gas pipeline.

During the infilling operation silt curtains are also deployed to minimize movement of silt out into open water.

Ballast Water Exchange a Potential Problem:

Shipping is increasing and as a result, larger quantities of ballast water is being carried more quickly and more frequently to an ever increasing number of locations. The transfer of harmful marine species in ship's ballast water has recently been identified as a growing world-wide human health, ecological and economic threat.

We have all heard of the Zebra Mussel problems in the Great Lakes, and the recent introduction of the Green Crab into the Gulf of Saint Lawrence. It now appears that an introduced marine species invades a new environment somewhere in the world every nine weeks.

The existing International Maritime Organization (IMO) voluntary guidelines for ballast water exchange is proving to have limitations in its safety and effectiveness. As a result the IMO is proposing a Ballast Water Convention which may include new regulations relative to the establishment of standards for removal of harmful aquatic organisms and also criteria for ballast water intake and discharge control areas.

In anticipation of these changes Environment Canada is participating with Transport Canada and DFO in the review of draft national guidelines. The local committee has conducted a literature review of ballast water issues, sponsored a preliminary study of the potential risks to east coast waters and conducted bench-scale testing of a number of promising treatment techniques.

The above mentioned study looked at the origin of ships discharging ballast in east coast ports, the volume of discharges by ship type, as well as the abundance and risk of introduction of indigenous and non-indigenous phytoplankton and zooplankton species. Preliminary results suggest that over one-half of ships entering Halifax discharge their ballast water and associated sediments.

Tankers and bulk carriers would appear to pose a greater risk than container and mixed cargo vessels, because they discharge the largest volumes and they retain water for a shorter period of time, and hence, tend to have a greater percentage of live organisms. Additional work is clearly required to further investigate the significance of this important issue.

Acknowledgements:

This paper could not have been prepared without input, assistance and the encouragement of the following Environment Canada staff: John Clarke, Rodger Albright, Wayne Barchard, Sinclair Dewis and Kok-Leng Tay.

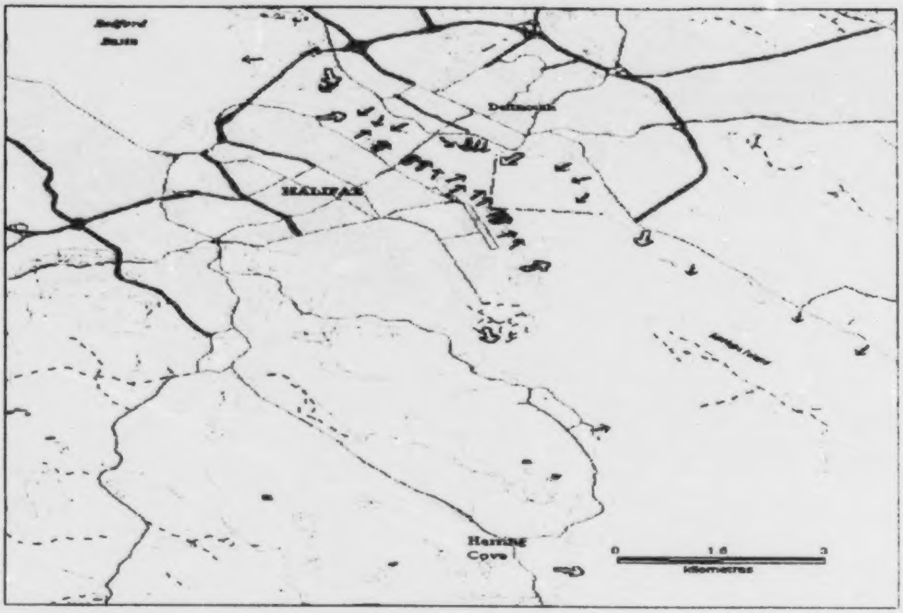


Figure 1: The location of existing municipal sewer outfalls and overflows; the seven largest are depicted with yellow arrows.

Figure 2: Canadian Forces Base Halifax shipyard with wet portion of vessel in synchrolift tarped for repairs.

Table 1- Major Municipal Sewer Flows - Halifax Harbour

Outfall	Million L/d	
Halifax		
Duffus Street	48.6	50 % of Halifax flow
Pier A	19.3	21 % of Halifax flow
Chain Rock Drive	12.2	13 % of Halifax flow
Dartmouth		
Dartmouth Cove	35	60 % of Dartmouth flow
Melva Street	5.9	10 % of Dartmouth flow
Burnside	5.7	10 % of Dartmouth flow
Herring Cove		
Herring Cove	35.4	100 % of Herring Cove flow
TOTAL FLOW	**186.5**	
Mill Cove STP	*22*	*(secondary treatment)*
Eastern Passage STP	*13.6*	*(primary treatment)*

Figure 3: Close-up view inside canopy showing sealed plywood decking on synchrolift plus sheathing to prevent dust emissions and paint overspray losses. All wash water and associated debris is collected for treatment or disposal. This canopy reduces weather downtime and offers better climate control for paint application.

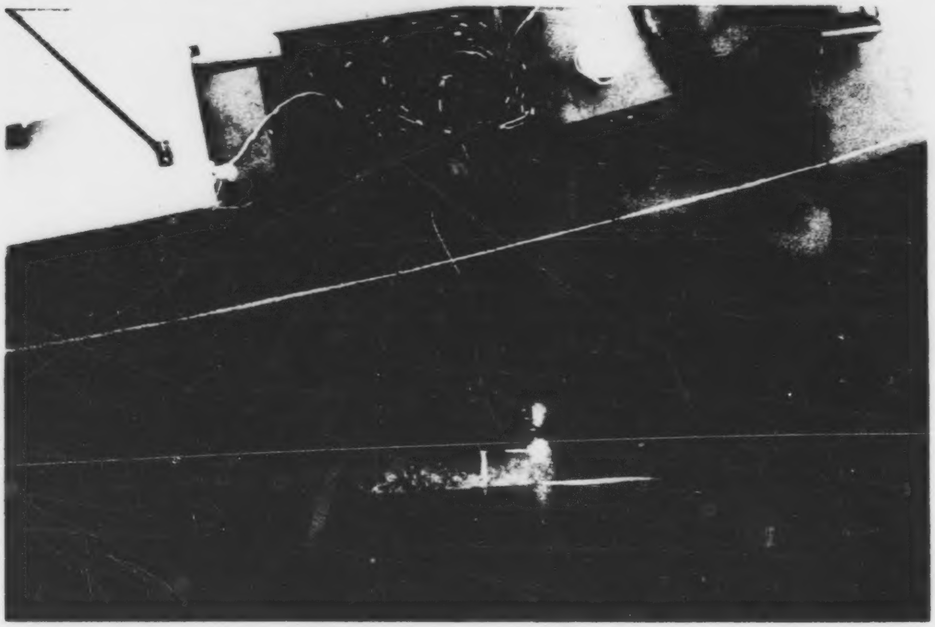


Figure 4: Divers polishing the vessel "Dynawave" to remove algal growth from the hull. Note: red anti-foulant paint being released into the marine environment.

Figure 5: Large red printing dye plume emanating from the Tufts Cove outfall

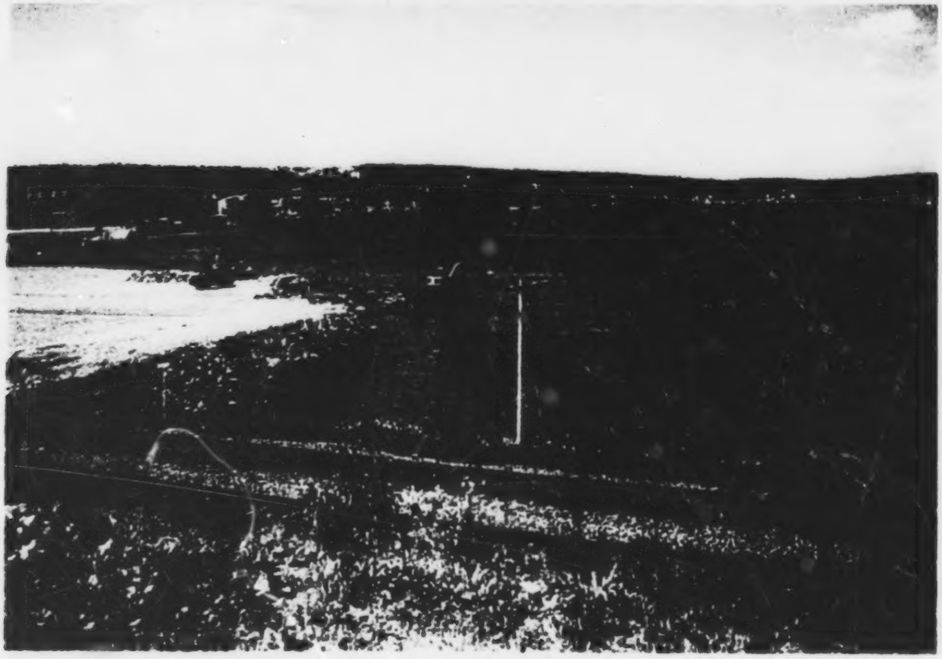


Figure 6: Phase two Bedford Basin infilling operation. Acidic rock is deposited below the low water mark and covered with standard rock fill. Silk curtains suspended from the red buoys minimize the migration of silt from the area.

Halifax Regional Municipality Pollution Prevention Program

John Sibbald

HRM has recently initiated a ***Pollution Prevention Program*** which consists of a combination of activities carried out by staff of HRM to inspect, monitor, enforce and educate industries, business and institutional facilities that discharge liquid waste to the sewer systems. Wastewater from these sources may contain toxic and hazardous chemicals which cannot be treated by municipal sewage treatment plants and may cause impairment to the marine environment of our harbour.

Wastewater treatment plants are only designed to treat common household wastes. Prohibited wastes such as hazardous chemicals, petroleum products, solvents and heavy metals which are discharged to the sewer system will pose serious operational problems by upsetting the treatment process, creating hazardous conditions for municipal staff and polluting the receiving waters of our rivers, lakes, ocean and our harbour.

HRM maintains a ***Wastewater Discharge By-Law W-100*** that sets limits on the strength and composition of wastewater that enters the municipal sewer system. This by-law will soon be revised and updated to reflect chemical concentrations consistent with other municipalities throughout the country. This by-law is a critical component of the Pollution Prevention Program as it empowers municipal staff of HRM to inspect, monitor and require industries to control the discharge of toxic and hazardous chemicals.

A series of question and answers have been provided to inform the reader of the type of activities that is being undertaken by HRM to reduce the pollution that impairs our environment.

Details of the Pollution Prevention Program which has also been referred to as the Source Control Program will be available on the HRM web site: **www.region.halifax.ns.ca** and will be supported through a program of educational and information releases which will be available to all businesses and residents within HRM.

Q. How will HRM know if industries are polluting?

A. *Staff of the HRM will regularly conduct inspections, monitoring and sampling of industries to insure that waste discharged to the sewer system is permitted. Many industries will be required to conduct their own environmental monitoring and regularly report the results to HRM. Random inspections of these industries will be conducted to insure that reported results are accurate and that no pollution has taken place.*

Q. What changes to the existing by-law will take place?

A. *The existing Wastewater Discharge By-Law will be improved with Council's passing of the proposed By-Law W-101. This new By-law is similar in many ways to that of by-laws in other municipalities across the country. The By-law will identify a broad range of specific chemical parameters and related chemical concentrations that will be prohibited from being discharged to the sewer system.*

Q. What penalties will be put in place for industries that continue to pollute?

A. *The draft by-law proposes that penalties for industries continuing to pollute will include fines of up to ten thousand dollars for each day that pollution continues.*

Q. What can residents do to assist the HRM in reducing the amount of pollution that flows into our harbour?

A. *Public acceptance and support of the initiatives that the HRM has undertaken to reduce pollution sources is critical to the success of this and similar programs. Individual residents may directly contribute to improving our environment and our harbour by promoting awareness and attempting to reduce the amount of chemicals used both in the home and at their place of employment.*

If you are interested in obtaining further information regarding this project, please contact either:

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Community Perspectives on Preserving the Environment of Halifax Harbour

Patricia Manuel

Introduction

In the early years of community associations with the Harbour, the question of community perspectives would have been pretty straight forward. Chebucto was likely a place of plenty. The waters would be thriving with life; fish from the bay, hunt and gather on the land - food was fresh, clean and plentiful. Who wouldn't want to be here? At one time the health of the Harbour was inexorably linked with human health. To even question any possibility other than a healthy Harbour environment would have been absurd.

Today, in our time, I would suggest that the Harbour environment and human health are still linked - we just define the needs of good health and a good life more broadly. We have so many more options available to us to satisfy our needs, since we are members of many different communities each with interpretations of what the Harbour environment should provide.

My intent here is not to enumerate or recite community perspectives - community members must speak for themselves. However, I will explore what we mean by 'community' and 'perspective', examine the complexity of the Harbour communities, consider (through generalization) some perspectives that have led us to major decisions about the Harbour environment and how we should proceed with improvements and how we have responded to community perspectives.

'Community' and 'Perspective'

'Community' is an assemblage. We think of it as the occupants, or people, of a particular place or region, sharing the same space or resources. A community is also a collective bound by shared experience and interests. Implied in the subject of this talk is 'the community' as 'the public' - members of the non-professional, 'non scientific' realm - those who provide the informed layperson and experiential perspective.

'Perspective'

And 'perspective'? To an artist, for example, 'perspective' is the view of an object or scene given to the painter, photographer, what have you, from a given position. Every position yields a slightly different perspective. When we speak of objects of thought, perspective is the idea, view or impression we construct, given our particular standpoint, our 'point of view'.

In the context of today's theme 'Preserving the Environment of the Halifax Harbour', we are exploring knowledge, ideas or impressions of the Harbour from different points of view: - scientific, administrative, community. Some perspectives are formed based on objective interpretation of measurable, reproducible 'data'; - others - specifically those of 'the community' - are, in contrast, experiential and not readily measured or appreciated using scientific or technical interpretation. This quality tends to make them somewhat ephemeral.

We have been hearing about different scientific, technical and administrative perspectives - biological, physical, ecological interpretations of what the Harbour is and what it might or could become; and how - with various approaches in administration and planning, we might achieve these outcomes. Different professional communities, different perspectives. So it is too with 'the community perspective'.

In order to access, understand and respond to 'the community perspective' we need to undertake a bit of deconstruction: identify the many and varied Harbour communities and consider their relationships - their vantage points - with the Harbour - the positions from which they form their perspectives. I will consider two main community positions, or points of view - that which comes from geography (location), and that which comes from experience (user perspectives).

Communities of the Halifax Harbour

Community by Geography

Halifax Harbour is big. If one were to walk the Harbour coastline from Hartlen's Point to Chebucto Head, trek the Harbour island beaches and stroll the Northwest Arm shore one would walk about 150 kilometers. Such a hike would be an instructive exercise. Locating access points is not always easy, but there are in fact many, and while the walk will require many detours around industrial sites, office buildings, lawns and dockyards, there are also many stretches of unobstructed shoreline. What one would certainly recognize is the extraordinary diversity of uses - the way people make their living from the Harbour, or enjoy the Harbour water and shore.

The Harbour of course surrounds Halifax Peninsula - the Harbour proper to the east, the Northwest Arm to the west. Peninsular Halifax alone has a great complexity of neighborhoods and land uses that suggest many different 'community' affiliations with the Harbour - tourism, recreation, historic-cultural, and military uses all dependant on the Harbour. The Northwest Arm side of the Peninsula is almost entirely dedicated to upscale residential neighborhoods - places that derive their substantial real estate value from the aesthetic and recreational environment supplied by the Arm. Dartmouth, Bedford and Rockingham bound the eastern inner Harbour and Bedford Basin shores. Again, we find a blend of commercial, industrial, residential and recreational uses associated with the Harbour. Sometimes, in our urban Harbour settings, the character of the immediately bordering community contains signs of its earlier association with the Harbour - such as in the Woodside neighborhoods, built to accommodate refinery workers - but more usually the working link is lost. Now, new urban communities are emerging to benefit from the Harbour aesthetic (such as the Bedford and Halifax waterfront residential developments).

Armdale sits at the head of the Northwest Arm and the beginning of the Mainland South or Chebucto Peninsula shoreline. Here, development is more limited and uses are largely residential or parkland. The bordering communities still display vestiges of their original recreation or fishing association with the Harbour.

At the Harbour entrance east and west are Eastern Passage and Herring Cove, both active fishing communities. They are sentinel reminders of the Harbour as a working place and a sustaining place.

Beyond the cities, villages and neighborhoods of the Harbour coastline is another layer of communities - Spryfield, Clayton Park, Sackville, Woodlawn. These communities reach back into the watershed. Their links may not be as visually direct as those of communities on the immediately ascending slopes, but they are still part of the Harbour through natural drainage or engineering.

The total population of these Harbour communities reaches 250,000 people - those who are most closely connected to the Harbour by nature or design, physically and biologically. But not all Harbour communities are 'housed' in these neighborhoods. Given its regional, national and international stature, geography has its limitations when defining the Harbour communities. The Harbour's reach is through perception and experience as well as geography. Hence, we also have the communities of 'users' or the communities of interests.

Community by Users

Users come in different forms. Halifax Harbour is a working harbour: it supports and is the focus of a huge military industrial and commercial infrastructure. The evolution of the entire region derives from these uses - from the fishery to the navy to offshore oil and gas to tourism to waste disposal and many other uses besides. But, as we work, we must also relax and play - the Harbour becomes a focus for our recreation. And furthermore, we are only the human users. We share the Harbour with other life and, through currents and tides, connect to the rest of the ocean world.

The community of 'users' is extensive: fishermen, sailors, tour boat operators, refinery workers, dockyard workers, naturalists, oceanographers, and so on. Each user community has its own requirements of the Harbour environment. Sometimes, these requirements conflict with one another, or impose on each other. Sometimes they are complementary. Furthermore, any one person can be a member of several - perhaps even competing - user communities - or, one's membership in a 'user' community and 'geographic' community may overlap, such as the fisherman from Eastern Passage, the refinery worker from Woodside, or the sailor living on Shore Road.

Where we live relative to the Harbour and how we use its total environment - water and shoreline - passively and actively shape our perspectives on the Harbour as a place now and what we wish it could become.

It is very difficult to clearly articulate community perspectives on the Halifax Harbour. These points of view are, by nature, experiential and anecdotal. Furthermore, they shift as the community becomes more actively engaged with the Harbour solutions process. To claim special knowledge of community perspectives would be misleading. I can only draw from the my experience with Harbour solutions discussions - review of earlier Harbour clean-up proposals, and participation in Harbour committees (the Harbour Solutions Advisory Committee and the McNab's Lawlor Islands Provincial Park Advisory Committee).

The perspective we build is typically from community members willing to, or forced to (as in 'host' communities), participate in the public participation process. Despite the best efforts and intentions, the public is not always well-represented in the process. It is self selecting: those most interested, those most likely to be adversely affected, are the ones most likely to get involved and so these are the perspectives we hear and work with.

What I find especially interesting is that, despite the varying positions within the community, we have been able to agree among ourselves on some very significant things regarding the Harbour environment that will move us forward. I'm also interested in the way we have responded or are responding to these perspectives - organizing what we know and building objectives and actions around them. We have, for example, perspectives of the Harbour as 'place', perspectives of the Harbour in the future; and perspectives of how we move into the future.

The Harbour as Place

The Harbour is widely viewed as the focal point of our local landscape. We see it from many vantage points and it become the location of many special events. To the geographic communities, it is variously part of the neighborhood, a distant backdrop, or unseen but there through awareness of its local significance. For user communities, it is where we go for work, or where we go for recreation.

The intensity of the Harbour 'place' experience shapes in our opinions of the Harbour environment. Hence, given the wide range of perspectives, I consider it an accomplishment that we managed to arrive at a widely shared perspective of one very central aspect of the Harbour environment - the Harbour is dirty.

Yes, we have debated what 'dirty' means - that what is fouled for one use, does not necessarily mean fouled for another. But, it is dirty enough to diminish the overall quality of our 'place' experience. And, we share the desire to do something about it.

I believe we used a sound approach in our response to these community perspectives when, eleven years ago, the Fournier Task Force defined water quality objectives based on human industry and human and environmental health requirements. The resulting three-zone classification combined the needs of user communities with the realities of Harbour geography (economic, political and cultural) and Harbour structure and process (physical and biological). With some adjustments by the later Halifax Harbour Solutions Committee, the classification has become the benchmark for establishing Harbour environment cleanup priorities. In short, the inner, most industrialized part of the Harbour, stretching from McNab's Island to the Narrows need meet the least stringent classification where water would be suitable for habitat, boating, industrial cooling and would have 'good aesthetic value' (referred to as class SC). The remaining Harbour waters would be safe for swimming and shell-fish harvesting with (Class SB) and without (Class SA, the highest class) depuration.

Now we are moving on to realizing our goal. Implementation is not easy. We need to remember it took a lot of debate to agree, as a community, on our environmental objectives so we can't expect that agreeing on how to do it will be any easier - we are discovering the truth in this right now.

In thinking about community perspectives on implementation, I went back to the deliberations of the Harbour Solutions Advisory Committee. The Committee articulated 12 Principles to guide it's recommendations. The principles derive from the Harbour Solutions workshop - which brought together scientists, administrators and the interested public - members of the Harbour communities. The workshop was in response to the failed HHCI proposal. We were looking for a new approach. It's interesting to review these principles in light of where we are now. I won't go through each one, but will highlight some of the key ideas - connecting community perspectives with actions.

Community perspective/principle - We defined water quality objectives based on user community needs. We have set a technical program around the Fournier water quality objectives, which are realistic from a 'users' perspective.

Community perspective/principle - There is a widely held community perspective that 'smaller is better'. We are opting for several smaller community-based plants.

Community perspective/principle - We adopted into principles the community perspective of 'do what we can now, not more than we can afford at the moment'. We are proceeding incrementally, as we can afford to do - prioritizing water quality areas of greatest need or greatest beneficial impact for the money spent.

Community perspective/principle - Treatment plants need to fit in with the surrounding environment. I am told this will be the case.

We also have principles on treatment innovation, source controls, waste water management, user pay equity and public participation, watershed management.

Some Harbour user and interest communities hold the perspective that we can and should be innovative, where possible and practical, with our approaches to sewage treatment. We adopted innovation into our principles but thus far, the technical program does not respond to this perspective of using alternative approaches. We hear concerns about environmental contaminants that won't be treated with our proposed approach. The community continues to advocate for alternatives that will remove further contaminants.

We have an elaborate public participation process: information sessions, workshop events with regional and community level consultations, citizen working groups. The principles call for on-going public participation and open, transparent decision-making. Some aspects of decision-making will be contentious and difficult, especially treatment plant location.

In reflecting on what I have heard and experienced of the community perspective, I can say that communities recognize and accept that some may well need to be host communities if entirely industrial or remote locations can't be found. But, it's true, no one especially wants the job. Unfortunately the technical requirements and realities of real estate narrow down the practical options very quickly. Geographic communities too often find themselves in the position of reacting to, rather than participating in, the decision that puts a plant in their neighborhood. We are in this situation right now.

In its discussion, the advisory committee promoted the principle of 'WIMBY' - 'want it in my backyard'. The idea is that communities vie for the opportunity to host a plant (should it be necessary to place one in a largely residential area), rather than using compensation strategies to soften the blow on an already selected community.

I think that certain community perspectives are well-represented in our current approach to preserving the Harbour environment. Others - community participation - especially as it results in certain aspects of equity in the decision making process - if that is even possible given technical and geographic constraints - may not be where we would like to see them ideally.

We have an emerging community perspective that we need to take better care of our lakes and streams. We see this in the increasing participation in watershed groups around the region. We adopted into principle watershed management as a means of controlling land based impacts on Harbour environmental health. We recognized the opportunity for wider community involvement through this approach. With our focus to date on the technical aspects of Harbour solutions, we haven't heard very much about action on this aspect of protecting Harbour environmental quality. Reaching into the Harbour watersheds is a tremendous opportunity for fostering stronger community links to the Harbour, especially as those the Harbour as place experience tends to weaken as we move inland. Reaching into the Harbour watersheds engages the Harbour communities in Harbour solutions - healthy land-harbour relationship - in a way the technical program can not.

I would like to offer one further consideration of the community perspective - one we don't hear much about, so far, but I think merits introduction in the context of preserving Harbour environments - access, specifically recreation access.

Harbour access - how we get to the places we want to visit or explore - is the way we make our connections of place with the Harbour. In the context of considering community perspectives of preserving the Harbour environment, one also has to think about enriching the Harbour experience: nurturing community perspectives that are positive, reinforcing continued support for a healthy Harbour environment, ensuring opportunities to experience the diversity of Harbour environments.

Harbour access comes in three forms - on the water, from the land at the shoreline and from the land at a distance - the Harbour view. Harbour shorelines include the developed and undeveloped shores. Our water quality objectives and geographic zones match activities suitable for these locations.

There are certainly diverse perspectives on the degree of access to the Harbour environment. If you have a boat, you likely have what you need to get on the water - if not a member of one of several private clubs - there are a number of public launches. Once on the water, access is extensive. Coming to the shore from land-side is another matter. If you have special knowledge of Harbour real estate you may hold the view that there is a lot of public land and access to the Harbour. Viewing a map, there is, in principle. But in practice? We need to differentiate between opportunity and actuality.

We see increasing access to the developed shoreline with the development and extension of boardwalks in the downtown and Bedford waterfronts. But we also need to consider the other Harbour experiences. The less developed or undeveloped shore is where we have set the higher water quality standards - especially the Northwest Arm and McNab's Island. Access to these less developed shorelines is intermittent and sometimes difficult.

I have been paying attention to this issue because of my role with the McNabs and Lawlor Islands Provincial Park Advisory Committee. With this park we will have available a very special Harbour experience offering Harbour access - views, water and shoreline - that is currently accessible only to those with the private means or the substantial taxi fare to get there. I encountered it as well on a visit - charter - to George's Island, which when complete will be a truly unique Harbour experience.

I began thinking about equity in relation to opportunities to use and explore the Harbour, and how inequity due to lack of means, or restricted or diminishing access due to shoreline development, may affect community perspectives of the Harbour over time.

It is a widely held community position to support what it takes to improve Harbour health. Some communities will carry a heavier burden in that regard. We need to foster wide and continued community support and endorsement. We can't rely on social and environmental altruism alone. We need to ensure equity on many levels - full involvement in decision making and greatest opportunity to benefit from the full range of Harbour experiences. These, I suspect, are community expectations.

With full participation we generate more ideas. Our ideas can't come from the scientists, engineers and managers alone. Community perspectives, given room to grow, will bring an even broader vision of Harbour health. Imagine what we could do, perhaps, with Harbour shoreline restoration? Why, for example, must we confine our efforts to boardwalks? There are many untapped community perspectives needing due consideration through full participation. They could be the source of what will really turn around the health of the Halifax Harbour environment.

Protecting the Visual Relationship between Halifax Harbour and the Urban Area.

Simpson McLeod

Synopsis

The focus of this brief paper is the visual relationship between Halifax harbour and the urban area adjacent to it, and more specifically, what has been done by the municipalities to protect or enhance that relationship. The nature of that protection and how it came about is discussed. It is significant that the major part of this protection is now 23 years old. Is anything else about to take its place?

Introduction

The 1960's is a significant watershed in this ongoing visual relationship between Halifax harbour and the urban areas that developed around it. Prior to that date, the urban area had grown fairly slowly, and the scale was modest. Buildings were for the most part two and three storey high, although in the Downtown core there were commercial buildings up to six and seven stories high. From the harbour, the skyline was still largely as nature made it, and when it was dominated by buildings, these were for the most part church spires, the odd smokestack, and the decorated tops of federal or civic buildings. Someone standing on Citadel Hill would have had an almost unrestricted view of the harbour from the Narrows to MacNab's Island and beyond. From a vantage point on the Dartmouth side, it was much the same.

At that time the urban waterfront was still largely commercial, owned by private companies, government agencies or quasi-commercial crown corporations that were all in transportation and marine trade in one way or another. They were on the waterfront because they needed access to water. This was a working harbour. Public access was severely restricted. At that time, it was not a place where you might take your family for a walk on a Sunday afternoon.

Progress In the 60's, things began to change:

- Local property developers began to build high-rise buildings. Office towers began to pop up in the core area, later to be followed by multi-storey apartment buildings in the older residential areas around the core, as developers responded to the market place and exploited new construction techniques, new fashions in architecture and new methods of financing.
- a very ambitious, well-funded and some what short lived federal program generally referred to as "urban renewal" arrived in Halifax. Most notably, at the northern end of the old Downtown, it started to create a major comprehensive commercial and residential redevelopment called Scotia Square and the first phase of an urban freeway, known as the Cogswell Street interchange.
- private commerce began to abandon the urban waterfront and move elsewhere. The old waterfront warehouses and plants became empty and derelict. In Halifax, the newly proposed Harbour Drive was planned to go right through some of these properties, to provide a

high capacity road link from the new Cogswell Street interchange through the Downtown to the deep-water harbour at the south end of the Peninsula.

By the start of the 70's, all of this began to alarm the community. Where people used to be able to stand on Citadel Hill and enjoy an open panoramic view of the harbour, now they began to see tall buildings sticking up. In Halifax, where there had been several normal sized city blocks, now there was one superblock. Where they were used to shops along the side walks, now there were blank concrete walls - and all the shops were on the inside. The area occupied by the new interchange was huge. The scale of these new structures was, in local terms, massive. It was not at all what the citizens were used to. The whole look of their surroundings was changing, and they didn't much like it. They weren't against change in some ultra conservative sense. They were well aware that there were new styles of doing business and new ways of living. In the 50's, the blocks now occupied by Scotia Square and the Cogswell Street interchange area had been a very rough, overcrowded, slum area, a "no-go" part of the town for most of the population. They didn't want to keep that - but they certainly didn't like what replaced it. The question was - what could they do about it?

Views from the Citadel

In Halifax, the initial focus of this growing public concern was the visual relationship between Citadel Hill and the harbour. In the middle 60's, the first two bank towers were built in the downtown, and by 1970, the first two office towers of Scotia Square were up, as well as the first of its residential apartment blocks on Brunswick Street. It was becoming clear that, if new development was going to continue in this manner, the broad panoramic view of the harbour from Citadel Hill, which citizens had enjoyed from the earliest days of settlement, would largely disappear.

The most outspoken opponents of this trend were those with an interest in history and Halifax's heritage. In their view, the relationship between the Citadel and the harbour was fundamental to an understanding of the area's past, and that would be totally lost if, in the not too distant future, a person on Citadel Hill could only catch glimpses of the water between high-rise buildings. Uncharacteristically for a federal agency at the time, Parks Canada, as custodian of the Citadel, publicly supported that position, and strengthened it by stating that the views from Citadel Hill were really part of our national heritage, important to all Canadians. There were, of course, arguments from the other side, with a strong pro-development faction expressing its concern over the damage that any form of height restriction in the Downtown would have on the area's economic growth.

However, City Council made the controversial decision, and in January 1974, adopted a bylaw that created ten viewplanes. They radiate from four viewpoints on Citadel Hill, and sweep in a 180 degree arc from Macdonald Bridge in the north, to Point Pleasant Park and Chebucto Head in the south. The logic of this approach was that each viewplane would protect a view from the Citadel to a specific location in the harbour that was historically significant, i.e. the site of a fort on the opposite shore, or a fortified gun emplacement guarding the harbour mouth, or a signalling station, all of which was part of the harbour's defensive system as it had evolved over the previous 200 years. These viewplanes, although they overlapped and crossed each other sometimes, did not protect the whole panorama. There were locations between the viewplanes that could accommodate high-rise buildings, and, of course, buildings could be built under the viewplane, although their maximum height would be very limited. In the Downtown core, the area of the original fortified settlement between Citadel Hill and the water, viewplanes covered just over half the total area.

This was a hotly debated issue at the time. There were testy public meetings and open Council sessions. There were rumours and threats of appeals against the bylaw. Several were launched but all were withdrawn before they got to the provincial Planning Appeal Board, so the bylaw became official. It is a very specific piece of legislation, and there is no discretion in its application. A proposed structure either infringes the bylaw - i.e. projects into the protected viewplane, or it does not. If the former, it is not granted approval. Council cannot waive its requirements, even if it wanted to. In its 27 years, it has never been contested.

On the Dartmouth side, there were similar concerns, but there was less development pressure at that time, and because of the difference in topography, they were able to protect an open panoramic view of the harbour from a vantage point on Brightwood Golf course. That became a bylaw in 1978.

The Waterfront

On the Halifax side, the view from the Citadel wasn't the only thing that concerned the citizens at that time. The fate of the urban waterfront also bothered them - particularly the proposal to continue Harbour Drive south from the Cogswell Street interchange as a high capacity, divided highway, to link up with the deep water terminals beyond the CN station.

At one swoop, this would have demolished what was left of the old wharves and waterfront warehouses in the urban core, and created a permanent barrier between the Downtown and its waterfront. Specifically at risk were Morse's Tea Building (Granville and Upper Water Streets) and the stone-built warehouses that now house Privateer's Wharf among other things, which at that time were scheduled for demolition.

Many of the same people who were active in the viewplanes debate also were involved in the move to save these buildings - Halifax is a small place. Eventually, an injunction was obtained to stop the demolitions and a proposal for the re-use of the property was submitted by a private company. This would retain the existing structures from Granville Street to the waterfront, refurbish them and add new buildings in a character that would complement the old. It was called Historic Properties. All three levels of government were actively involved in this project. In addition, Parks Canada became an anchor tenant in the waterfront portion of the project, and the province, on behalf of the Nova Scotia College of Art and Design, became the anchor tenant on the other side of Upper Water Street.

Quite apart from saving these heritage buildings and giving them a new lease on life, this initiative totally squashed any thought of extending Harbour Drive along the Downtown waterfront, which of course was one of the principle objectives. With these buildings preserved for the foreseeable future, that proposal died. And from that instant, it was clear that the Cogswell Street interchange was hopelessly over designed and probably redundant, but it has taken us 25 years to collectively come to grips with that thought, and only now are we able to seriously think about removing it. From a traffic engineer's perspective, not proceeding with Harbour Drive has made it very difficult to move port-related truck traffic on and off the peninsula, but, from the community's point of view, that was a price it was prepared to pay for maintaining the kind of Halifax it wanted.

A direct spin-off was a new approach to the waterfront, to try to see it not just as a mish-mash of old piers and derelict buildings, but an opportunity to create a more dynamic, attractive mixed-use environment. An intergovernmental committee was set up to examine the potential for alternative uses, and ultimately that led the establishment of the Waterfront Development Corporation (WDC), which at that time was a joint federal-provincial crown corporation. It was generously funded, with a mandate to invest in infrastructure - streets, sidewalks, services - and promote the development and re-use of under-utilized buildings and lands. The intent was to maintain the working waterfront to the greatest extent practical, but also to encourage public access, public open space and public activities as well. It was to have a continuous boardwalk along the waters edge. It was to become an active "people place," and, hopefully, tourist destination.

In its role as midwife for this new waterfront environment, the WDC carefully considered how it wanted new buildings to fit in, in a visual sense. It was not so much concerned with architectural detail, but more about the height of new structures, how close they should be to the boardwalk, and matters like that. Eventually, they settled for an "amphitheatre" concept, with the water as the stage and buildings arranged in tiers up the hill. In its simplest terms, buildings next to the water were to be kept low and as buildings got further back from the water, they could become taller. Essentially, the intention was to prevent a tall building, or wall of tall buildings, lining the waterfront and visually cutting off everything that lay behind it from its relationship with the water, and depriving it of this important link with the harbour.

The WDC, in conjunction with municipal planners, prepared a set of prescriptions, on a block by block basis, for maximum heights and set-backs for buildings, to put this amphitheatre concept into effect. Unfortunately, these controls were not made part of the legislation in the same way that the viewplanes were, and, instead, were adopted as a set of guidelines. Staff has referred to them consistently, but guidelines require cooperation to work. If the client for a new building happens to be a public body - for example, Maritime Museum of the Atlantic - the guidelines can be put into effect through persuasion and goodwill. If, on the other hand, the client is a private commercial firm - for example, Summit Place - then they really have no teeth.

East-West Streets

In the Downtown area of Halifax, east-west streets run from Citadel Hill down to the waterfront. It is recognised that the views up and down these streets are important for the visual appreciation and understanding of the old urban core. In particular, anyone looking down these streets should be able to see open water at the bottom. That is now incorporated in municipal legislation (Municipal Planning Strategy). Those of you who know Halifax will realise you cannot see open water when you look down Duke Street, where the Court House blocks the view. In that case, the building of the Court House pre-dated the legislation and, in fact, the impact of the Court House had a lot to do with the introduction of this particular control. More recently, on the positive side, the WDC acquire the former DFO labs on the waterfront at the foot of Prince Street. Most of the old buildings were demolished, which, among other things, opened up a vista to the water that had been previously closed off by a two storey "temporary" metal structure that had been there a long time. Another aspect of this same provision is that the municipality strongly discourages the construction of upper level pedestrian bridges over east-west streets, for the reason that they would interfere with an open view to the water.

In retrospect, I find two things remarkable about all of this. First, although the concerns and frustrations about urban change had been building for a while, the reaction, when it came, led to an amazing out pouring of community energy in a relatively short space of time - about seven or eight years, altogether, from the early to the late 70's. And what is briefly outlined here is only part of a bigger picture. Much more has been going on, all of it having a very direct bearing on the way urban Halifax has evolved over the last 25 years. This includes the character of the Downtown, what its streets look like, how new development applications are reviewed and approved, heritage protection, and more. It is all contained in the Municipal Planning Strategy for the old City of Halifax, approved in 1978.

Secondly, it also astonishes me that the Plan has not since been reviewed or substantially changed since. It has had new sections added to it, to provide more detailed planning direction for certain parts of the urban area, but not for the Downtown core, nor has the overall form and intent of the document changed. Only now are we getting round to having a second look at the Waterfront area. A more comprehensive review is long overdue, but the amazing thing is that it still all seems to hang together

Recent Activity

Although there was a bit of a hiatus in the 80's and 90's as far as planning initiatives were concerned, a number of projects were carried out at that time to improved the waterfront at various locations around the harbour and gave the public visual access to the harbour. Several small parks and open areas were build such as; Sackville Landing, Chebucto Landing and Seaview Park in Halifax, Alderney Landing in Dartmouth. As well, a large, new open space at the very head of the Bedford Basin has been developed, which affords one a tremendous view to the Narrows. Of course, Point Pleasant Park has always been an excellent vantage point for views of the outer harbour, and that still remains.

Recently, in July, 2000, HRM adopted a plan for Downtown Dartmouth, which, among other things, seeks to enhance the relationship of that area to the harbour by ensuring that views down streets towards the waterfront remain open. In this manner the viewer can see open water, and by creating a viewplane from Dartmouth Common that protects the view towards George's Island, a large part of the inner harbour and Downtown Halifax.

Furthermore, WDC and HRM together have recently commissioned a review of the Waterfront section of the Municipal Planning Strategy that applies to the former City of Halifax. That has been prepared by a well-known and highly regarded firm of local planning consultants called EDM . I was fortunate enough to have been involved in that study in a minor way, and am impressed with the end product. I find their proposals both visionary and practical. But, and this does NOT sadden me, I do not find much that is essentially new. The major themes from the old plan and guidelines are there, i.e. the boardwalk, which of course is now largely complete, the views down east-west streets, open space on the waterfront and the control of building heights that is similar in many ways to the "amphitheatre" concept alluded to earlier. Where EDM's plan excels is that these themes are clarified, strongly linked to the rest of the Downtown, and consistently worked out to a level of detail that has not been achieved before.

However, that Plan, good though it is, has not yet been officially adopted, and it remains to be seen what kind of municipal document it will turn into, and how strong a piece of legislation it will be. How much discretion will it allow? Will it have real teeth? It is only natural that Council, as a body, will choose to reserve for itself as much discretionary power as possible.

But I believe the WDC Board will seek a clear unequivocal statement that leaves little doubt about what can or cannot be built on waterfront lands, so they can negotiate with developers accordingly. Essentially, that would mean a fairly tight piece of legislation, with clear prescriptions and a minimum of discretion.
It will be interesting to see how this will be resolved.

SMcL Mar/01

Recovering Lost Habitat

Bob Rutherford

The restoration of the Halifax Harbour's aquatic ecosystem health depends on a common vision of what we want to achieve. Until we have a thorough discussion, which takes into consideration our social, economic and environmental values and how collectively we see Halifax in the future, we cannot move forward on recovering lost habitats. Most management initiatives will be frustrated by continued site-by-site confrontation and inaction on the basic underlying issues. This inaction will ultimately result in an overall decline in ecosystem health and the subsequent loss of habitats as the city grows.

Restoring Halifax Harbour's aquatic ecosystem health can best be done in the context of a comprehensive management plan for the harbour and adjacent watersheds. This plan should be developed in collaboration with all interests and be agreed to by all three levels of government, including all relevant departments, commissions, agencies and boards. With their support of the plan and collaborative implementation with all other interests in the area, we can stop the decline and return the ecosystem to a state of health that will be an asset to the community of users.

This is a major task, but it can be done.

A lot of the work has already been completed through Workshop #1 "Preserving the Environment of Halifax Harbour", Harbour clean-up reports, Waterfront Development planning processes and HRM land use planning. This workshop is another good step forward. Whether or not we need ecosystem restoration at this time and how far we need to move back toward the 'pristine' depends on the vision we develop.

Who will lead and facilitate the process?

This is not for me to say, and is of course, a decision to be made by the departments, commissions, agencies, corporations, industry, community groups, or in short all interests. However, because of the diversity of issues and jurisdictions, it would seem to make sense that those with broad planning mandates would work collaboratively to lead this process.

In the last workshop it was suggested by several discussion groups that HRM take the lead. If they are able to do this it would be great, because of their strong planning capabilities and obvious interests in land use issues, but they will need the strong and active support from provincial Departments, particularly the Environment, Health and Municipal Affairs portfolios.

DFO, through its mandate under the Oceans Act, as the federal lead in coastal management planning and implementation, as well as its strength in coastal ecosystem science, should also be a major collaborator to bring both a marine and federal focus. How this proceeds should be a topic of discussion at this, or future workshops.

What area should be covered?

Development has a strong tendency to move out along the coast. A plan with an aquatic ecosystem vision and indicators of health covering just the Harbour could encourage this development sprawl if land use planning controls in the adjacent areas don't keep pace with those in the Harbour watersheds. We are already seeing the spread of urban development to coastal areas, along the Eastern Shore and toward St. Margaret's Bay, which will place serious pressures on ecotypes which are much more sensitive than those in the harbour.

Consideration should be given to including these areas in the overall plan. Expanding the area will also allow for more flexibility in zoning for industrial, residential, natural, and protected areas of the coast to reach a balance which is acceptable overall.

Who will be included?

Everyone must have the opportunity to participate.

There are several management models and approaches in the Maritimes and internationally which have attempted to be all-inclusive, each has its own strengths and weaknesses. Experience has shown that the most successful organizations have a strong lead with adequate resources, a commitment to work toward the plan and its implementation for the foreseeable future and a mandate to lead and facilitate the planning and implementation process. To be effective, the core group must be small.

This organization will be challenged to find ways to build the capacity or understanding in all segments of society, including government, so they can participate effectively; to make the process open, transparent, and collaborative in both the planning and implementation steps; and developing clear rules on how decisions are to be made. To meet this challenge in Halifax will take commitment of the key management bodies and the networking of current institutions and processes.

What is the vision?

The next task is to discuss and agree upon what we would like to see in Halifax Harbour over the next 5, 10, 20 years.

Where do we want to be from the social, economic, and ecosystem perspectives?

This vision has to fit within the broader context of international "soft" law, conventions, and agreements, which define acceptable and unacceptable outcomes for the marine aquatic ecosystem and society. We can't turn the Harbour into a cess-pool, but it doesn't need to be pristine either. Also we don't need to meet all requirements within the Harbour, but if we don't, they have to be balanced off elsewhere with controls to ensure the balance is maintained for future generations.

The vision also has to match or fall within national, provincial, and municipal laws and regulations and be consistent with government policies. However, this still leaves quite a degree of latitude to develop a vision for the Harbour and flexibility for management.

From the ecosystem perspective we have to be realistic. Halifax is a major industrial port with good prospects for growth. There are historical impacts from human use that we will have to accept because they are required for economic reasons. Others cannot be mitigated or restored at a reasonable cost. For example, there has been substantial infilling with a total loss of aquatic habitat, and there are contaminants in the sediments which would be very costly to clean up, if in fact it is technically feasible. On the other hand, there is a lot we can do to reduce our current impacts and keep future impacts within more acceptable bounds. This will restore some ecosystem variables to acceptable levels.

The question is where do we want to be?
Do we want to preserve the Harbour the way it is now? Is that acceptable? Or the way it was in 1986 when DFO's Habitat Policy began to keep the books on 'no net loss' with a vision of a 'net gain of productive capacity of fish habitat'? Or can we come to an agreement on another vision of how to use the ecosystem assets of the planning area? What is acceptable and what is unacceptable?

Once we have the vision we have to define it with measurable indicators. Some are obvious, lower coliform levels <200 for swimming, <14 for shellfish harvest depending on the vision. Others are more complex, such as trophic or food-web balance, while others are social and economic. Some will have "hard" numbers as target levels while others will be more intuitive or soft measures.

We might consider zoning the Harbour for different uses with specific visions and indicators for each zone within the overall vision. What and where should these zones be, and what the management trigger levels are for each of the indicators, is open to discussion.

What is the current status?

The next step is to assess where we are now in achieving the vision. Where do we stand now on the indicators of health? Do they fit within the vision? Are our social, economic, and ecosystem components of the vision in balance or are there some incompatibilities?

Currently there are projects planned or projected for the near future such as new sub-division development. Do they fit the new vision and zoning or will the added pressures force indicators into the unacceptable range?

Where will the current and proposed management processes, guidelines, regulations and laws take us? Will the outcome be unacceptable or do we need changes now to curb the trend in development.

When we reach this point we should revisit the vision to see if achieving it is feasible. Or will it need to be revisited?

Action Plan

Now that we all agree we know where we are going, we need an action plan to get there and to keep us there in the future. This plan will set out what needs to be done to bring the indicators within the acceptable range. Who is responsible for monitoring each one or class of indicators and who will action a defined plan to get all relevant parties involved in getting back into the acceptable range if a trigger point is reached.

Many indicators will be in the unacceptable range now. Sewage is a good example. This will require the immediate or phased implementation of the action plans as soon as possible.

Moving from the unacceptable to the acceptable is restoration whether it is applied to the environment/ecosystem/habitats or social or economic aspects of the vision.

Restoration of aquatic ecosystems or habitats

If we stop current impacts and wait, nature will restore itself over time. We can speed up the process, in some cases by two orders of magnitude, by working with nature to restore freshwater and most coastal ecosystems to the level envisioned even if this is to pre-development, near natural levels. The key is to have the human management structures in place to effectively control our impacts, then to look for the variables that limit the health of the ecotype. These may be physical and chemical parameters such as: temperature, depth, cover, exposure, oxygen levels, metals or man-made chemicals, etc., or biological such as: bio-diversity, food-web, productivity, or association of habitat types, etc.

Normally we start with indicator species or assemblages of species and define their needs by life stage and the size and distribution of the habitats they need. Since we always seem to be limited by funds, we need to identify areas where we can effectively work with nature. If this can't be done for high priority, highly valued species, ongoing intervention in one or more life-stages is possible (i.e. hatcheries), but this is a very expensive and an ongoing cost. Restoring the natural habitats and their productivity is the preferred way to go.

Conclusion

To restore the aquatic health of Halifax Harbour, we need to put a collaborative management process in place that includes all interests and is championed by government departments with broad planning mandates.

The vision of what is acceptable and unacceptable in each zone, combined with an assessment of the current situation and planned development, will define the aquatic ecosystem protection and restoration requirements.

Restoration of the aquatic ecosystem or species habitats is technically possible even if the vision is to bring the site to near pristine. However, the more pristine the vision of the Harbour is the more it will cost in dollars, social change and impact pressures on nearby ecosystems. It might be best to moderate our vision of ecosystem health to recognize this area as an industrial harbour, and just bring it within the bounds of federal/provincial laws. This could be done cost effectively and would allow us to focus our resources on protection of nearby healthy ecosystems under pressure from the city's growth and the restoration of watersheds and coastal areas, which are less challenging, less costly on an area basis to restore to high quality and productivity, and where results will be quick and support the local resource-based economy.

This approach is consistent with coastal planning concepts and would meet the fish habitat management policy guiding principle of no net loss by restoring similar nearby habitat for an overall net gain.

Summary of Workshop #1 Recommendations

Brian Nicholls, Chair

Preserving the Environment of Halifax Harbour, Workshop #1, was held on March 14-15, 2000. The first day-and-a-half of the workshop consisted of sessions in which papers were presented under the following topics:

(1) Halifax Harbour – An Ecological Entity;

(2) Anthropogenic Stresses;

(3) The Regulatory Environment;

(4) Non-Regulatory Primary Stakeholders.

Six poster papers were also on display that presented information on the harbour and its environment. Based on the workshop presentations, a "Matrix of Human Activities vs Regulatory and Administrative Responsibilities in Halifax Harbour" was produced, and is included as an appendix to the published proceedings.

The main purpose of this first workshop was to gauge the interest of regulatory agencies and non-regularity stakeholders in the proposed launching of a new initiative on the restoration and preservation of Halifax Harbour. It was not the intention that this first workshop should develop and approve specific recommendations in support of such an initiative, its purpose being to ascertain the level of interest by participating agencies. However, on the final afternoon, and as a key part of the workshop process, the opportunity was provided to participants to take part in discussion groups under the theme "Looking into the Future." There were six such groups, and their findings (identified issues and suggested actions) are presented below by broad category[1].

Purpose, objectives of proposed initiative to preserve the environment of Halifax Harbour

- need for common vision of the harbour
- produce "White Paper" on goals & objectives

Lead /coordination mechanism/forum

- decide mechanism, e.g lead agency, small group of key players, "benevolent dictator"
- majority of participants considered that lead agency should be HRM
- role of HRM needs clarifying
- need for champion(s)

Consultation

- develop process to determine peoples' needs
- get the public involved
- seek input from the local community, including watershed groups & schools

Planning & management

- develop harbour management plan that includes "all the pieces"

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[1] Note that while each individual discussion group focused on a specific topic (provided by the organizers–refer to proceedings for details), this summary combines the findings of all groups according to common categories.

- need for integration of the existing "regulatory maze"
- need for harbour-use zoning (tie-in land uses)
- examine governance models
- address reguatory, etc.overlaps among various levels of govt., departments, etc.
- include public health issues

Information requirements

- list of experts
- information pamphlets on regulations, approvals, etc. specific to different types of proposal
- review of previous studies of the harbour
- review of similar initiatives elsewhere
- symposium on Halifax Harbour
- baseline inventory

Specific suggestions re. preserving the environment of the harbour

- improve public access, e.g. walking paths
- clean-up of floatables, etc. by community groups
- enhance existing fish habitat
- create new fish habitat, e.g. artificial reefs
- address habitat needs of wildlife other than fish
- safeguard wetlands
- address known key issues, e.g. leaching of solid waste deposits, contaminated sediments

Public relations and education

- public education & public awareness are important; need for plan to address these
- publicize successes

The findings of Workshop #1, as summarized above (and as presented in more detail in the published proceedings), were not formally adopted by the workshop. They are herewith presented as provisional findings for the information of Workshop #2.

Questions and Answers
Part 4

Question:
Mr. Blouin, has there been any work done on the cleanup of Mill Cove?

Tony Blouin:
No not specifically.

Question:
In examining methods of sterilizing treated sewage water, why did you not consider gamma radiation and what made you decide to go with UV radiation for the treatment process?

Tony Blouin:
Our consultants recommended UV treatment on the basis of it's proven effectiveness in other situations. The Harbour Solutions group is not aware of the use of gamma radiation as a possible practical ,and cost effective method for sterilization.

Question:
What about the effectiveness of UV radiation water penetration re-treating effluent from treatment plants? Is there a potential water clarity problem?

Tony Blouin:
It is our understanding that the plant process will provide water of sufficient clarity to be effectively treated by UV radiation, In addition, the water will be maintained at a sufficiently shallow depth where UV treatment is carried out to insure it is effective.

Question:
How will the compost created by the plants be used, is there any plan to use it on golf courses?

Tony Blouin:
At present there are no specific plans to use compost on golf courses, but I'm sure this will be considered as planning progresses.

Question:
What is the status regarding environmental assessment for the plants and the proposed process to be used in them?

Tony Blouin:
The plan for construction and the process to be used are in the final stages of completion. They will then be submitted for public review, probably using a form of committee representing stakeholders. It is likely that DFO will also have to prepare an environmental assessment screening report on the project.

Question:
Once the plants are operational, is there a potential for airborne pollutants escaping the plants during the treatment process?

Tony Blouin:
No, the plants are totally enclosed and will maintain a negative pressure inside, so that whenever a door is opened air will rush into the facility not out of it. In addition any air released from the facility will first be scrubbed to remove airborne particles.

Question:
Mr. Cairn, if financing was available, how would you treat contaminated sludge from the Hamilton Harbour?

Victor Cairn:
We did have funding initially to treat some of the sludge off the bottom in the coke ovens of the Hamilton steel plant: however, the plant union would not approve the project, fearing possible health risks to workers. There is at

present no other plan available, although it is being studied.

Question:
Are carp a biological/fisheries problem in Hamilton Harbour now that some areas are being reopened for fish access?

Victor Cairn:
Yes they are a definite problem just by their sheer numbers. We have had to take steps to prevent them from entering certain bay areas to allow aquatic vegetation to regenerate. We need to develop a better prey/predator relationship with respect to carp, so that their population can be held in check by natural means.

Question:
How are other cold water fish species and invertebrates fairing in Hamilton Harbour?

Victor Cairn:
They are not fairing well at all due to water temperatures in the Harbour which still remain too high for cold water species, and because of the anoxic conditions on bottom which persist over extended time periods in the Harbour. It will be a long time before Harbour conditions can be improved to a stage where cold water species will survive.

Question:
Mr. Percy, I think everyone recognizes storm water discharge as a problem. Is there presently any work being done to identify the extent and scope of the problem? Does Environment Canada do any monitoring at all on storm water discharge?

Roger Percy:
We do recognize storm water discharge could be a problem and prevention is quite difficult. At present Environment Canada is not doing any monitoring in this area.

Question:
Mr. Sibbald, you have indicated you will be looking closely at potential point source pollution sites throughout the HRM area, will you be using certified laboratories to do the testing?

John Sibbald:
We will be using certified laboratories.

Question:
Should you have to go to court because of identified pollution problems, what will be your source of data? Will it be collected by your own inspectors or by third party (possibly from the industry itself) monitors?

John Sibbald:
With respect to a court case we will use our own data. It should be noted also that should we use third party monitors to collect data, we will periodically spot check their data for accuracy.

Question:
Are garborator which flush contents into the sewer system still in use in the HRM area?

John Sibbald:
Yes they are still being used. There is no bi-law preventing their use.

Question:
When you mention looking for point source pollution in the sewer system, are you talking about combined storm and sewage sewers as well?

John Sibbald:
When required we will monitor combined

sewer systems, but as much as possible we will get as close to the potential pollution source as possible in our sampling. This probably means we will usually be monitoring either sewage lines or storm sewer lines separately.

Question:
Ms. Manuel, how do you get the community involved in the Harbour cleanup issue and how does the municipality reassure the interested public that they will try to do what is right for the Harbour environment?

Patricia Manuel:
To get the public involved, and to see that the public is reassured regarding their actions in the Harbour, it is necessary to see that they are kept aware of activities and progress regarding Harbour cleanup through newsletters, workshops, public meetings, etc.

Question:
Would you consider McNabs and Wood Islands to be more or less in their natural state?

Patricia Manuel:
Yes, I would say so, especially in relation to the more developed mainland shores.

Question:
Mr. Rutherford, considering the Harbour in the context of a watershed, is it possible that citizens could lead the process of seeing to it's rehabilitation rather than HRM?

Bob Rutherford:
It is feasible that citizens of HRM could lead the clean-up process, but it would have to be collaborative and would take serious commitment.

Part 5

Workshop: Developing Recommendations

Part 5 – Workshops: Developing Recommendations

Introduction

The participants where divided into six separate groups and were asked to work at elaborating a statement or motto that would reflect a vision for the future of Halifax Harbour. It had been intended that one or more of these statements or mottos would be adopted by the workshop as the recommended vision statements to spur the preservation activities for the environment of Halifax Harbour. In addition the participants were asked to formulate several realistic recommendations aimed at identifying the knowledge gaps, abating or containing contamination sources, preserving existing habitats and, enhancing aesthetic and other values of Halifax Harbour.

Following one hour of debate each of the six rapporteurs presented the highlights of their group discussion to the assembled workshop participants. The original rapporteurs reports are presented in Appendix B.

A Vision Statement for the Future of Halifax Harbour

The participants were unanimous in the belief that to improve the present state of the harbour's natural environment will require a favourable political climate and that it will also require a long term commitment at all levels of involvement.

To help sustain the initial momentum, the groups were asked to elaborate a statement or "motto" that would contain a vision for the future of Halifax Harbour. All six groups provided such statements (Appendix B). However, in the opinion of the Chair and Editors, one additional statement, given as a parting thought in the Group 6 Report, seemed to capture the imagination of all present best of all.

"Halifax is its Harbour. "

This statement, although brief, implies a tight link between a natural inlet and the human infrastructures on adjoining lands. It appears natural, and therefore realistic, to hope that the pride, love and attention the cirizens bestow on their communal environment, can be made to overflow on the body of Ocean that surrounds it. On the basis of that premise we should expect the Halifax Harbour to be afforded an amount of care and nurturing equivalent to that given to our towns and cities.

The adoption of this short statement as a motto reflecting the vision for the future of the Harbour is recommended.

Recommendations for the Preservation of the Environment of Halifax Harbour

The six working groups delivered over 35 separate recommendations to the plenary assembly. As can be seen in the rapporteurs reports (appendix B), all these recommendations bore on the revitalization of Halifax Harbour's biological environment, aesthetic values and public involvement. The editors sought to find the common points between these statements and so they were able to reduce this large input down to five (5) major developmental recommendations and nine (9) specific (pro-active) recommendations. All recommendations are listed below in order of priority without reference to the originator groups.

Major / Developmental Recommendations

- Establish an independently co-ordinated, jointly funded group, whose purpose will be to:
  - Develop an overall action plan
  - Galvanize and consolidate stakeholders participation
  - Gather, digest, disseminate and consolidate information
  - Identify and address knowledge gaps
  - Determine Habitat quality goals
  - Report on the integrity of the Harbour ecosystems
- Seek the commitment and involvement of the three levels of government (NSDOEL, HRM, DFO, EC) and work at fostering a political will to resolve the environmental problems in Halifax Harbour
  - Move the workshop ideas to City Hall
  - Involve the inhabitants of the Inlet
- Develop an electronic data base inventory of Halifax Harbour ecosystems, its pollution and contamination sources.
- Seek input from all levels of stakeholders, particularly the community at large
  - Establish community based monitoring
  - Design projects to be executed by community groups.
- Establish usage zoning as a management tool.

Specific (Pro-Active) Recommendations

- Separate domestic sewer system from storm run off over next two decades.
- Conduct a systematic assessment of all contaminants and continue the elimination of single source points (HRM source control).
- Promote the study of biological indicators
- Reduce Pathogens and Toxins.
- Promote the creation/improvements of physical numerical models of primary forces acting on the Halifax Inlet (wind, water currents etc.).
- Promote plans to improve aesthetic values of Halifax Harbour.
- Promote projects aimed at enhancing landscape values.
- Promote plans and works aimed at restoring Freshwater habitats and marine shoreline habitats in the littoral and sub-littoral zones for macrophytes. (shoreline remediation).

- Review Industrial Development projects one at a time in order to seek remediation and or compensation for affected or lost habitats.

Concluding Statement On The Future of Halifax Harbour

During two workshops held in March 2000 and 2001, over 130 stakeholders were consulted. These people represented the three levels of Government, industry and a broad cross section of the inhabitants of the Cities and Towns established on the shores and in the watershed of Halifax Harbour. The first workshop (2000) concentrated on establishing Halifax Harbour as a living ecological entity and describing the regulatory environment in some details. The second workshop (2001) described and discuss the biological environment conditions in the Harbour, reviewed the available scientific knowledge and assessed the impacts on fish and fish habitats of over two hundred years of use as an industrial sea port. The final output of the second workshop was to develop a vision for the future of Halifax Harbour and a series of recommendations for stakeholders activities to work towards achieving predetermined goals.

Through these two workshops the Halifax Inlet was revealed as a surviving ecological entity. Although the Harbour has lost much of its pristine value and appearance, the participants of both workshops were unanimous on the importance of preserving and enhancing the natural resources of Halifax Harbour for future generations to enjoy. Workshop #2 participants where also unanimous on the need and value of HRM's present sewage sanitation project, but there was general agreement that many more serious problems would continue to exist long after the sewage problem was brought under control unless concerted and sustained action is taken. The problems relate principally to water column and sediments, metal and organic, contamination from a multitude of sources, the cumulative impacts of harbour shoreline and bottom manipulation, such as dredging, infilling and the impacts of overall shipping activities past, present and future.

Workshop #2 participants fully recognized that revitalization of the harbour and its watershed must be a long-term undertaking, for example 10 years are predicted to complete HRM's proposed sewer treatment system. However some of the data presented by scientists at the workshops already revealed a reverse trend in contaminants accumulation in the sediments due to source control measures put in place two decades ago. The presence of such encouraging signals in the environmental data was noted by the participants, who in addition wish to see the implementation of a renewed systematic and well co-ordinated effort to rid Halifax Harbour of pollution and as much of the contaminants as possible. It was conceded that little can be done about some pockets (hot spots) of contaminants buried deep in the sediments. The participants also expressed a clear desire to see efforts made toward recreating lost fish and wildlife habitats and lost aesthetic values. They all accepted/agreed that Halifax Harbour must remain a multiple use body of water. The legitimate demands made by industrial concerns were accepted but not at the expense of other values. In conclusion, the common will of the workshop participants could be expressed as follows:

Within 25 years Halifax Harbour must be a healthy environment that offers sustainable multiple use, where biological and aesthetic

values are maintained and enhanced through integrated management. The decision making process must be knowledge based as much as possible but cautious in the absence of specific knowledge. The community must be well informed, involved and committed.

Part 6

Poster Presentations

The Fisheries of the Halifax Inlet

Andre Ducharme & Paul Rozee

Introduction

The information presented below is based on a 1989 survey of the Halifax Inlet fisheries. The information gathered is largely anecdotal. Nevertheless it is believed to be a fair reflection of the fishing conditions at the beginning of the 1990's.
A surprisingly large fishing effort still exists in all parts of the Halifax Inlet. Lobster is the principal species but many finfish are also harvested (cod was banned in 1994) on an occasional or part time basis. This fishery has never been monitored as a separate entity therefore the landings for lobster and finfish are best estimates drawn from the experience of interviewed fishermen, buyers and Fishery Officers.

Lobster Fishery, Basin, Narrows, North West Arm:

The northern tip of MacNab's Island and the Halifax Container Port mark the upstream limit for serious lobster and finfish fishing. Two to three fishermen however, consistently fish for lobster upstream of this line. Approximately 300 traps are set annually along the shore of Bedford Basin, in the Northwest Arm, around George's Island, and on the north shore of the main harbour form the Dartmouth Ferry Terminal to Irving Oil Wharf. Some recreational fishery also takes place at the mouth of the Sackville River for salmon and gaspereau. Minor hand lining for cod and haddock is carried out at Seaview Point. In the past lobster was also fished from Seaview Point to the Volvo Plant but seabed manipulations resulting from past construction or dredging activities may have destroyed the lobster habitat in this area.

Lobster Fishery Inner/Outer Harbour

Serious lobster fishing occurs throughout the inner harbour and outer harbour from the northeastern tip of MacNab's Island (Ives Knoll), south to Sambro Head and eastward from Thrumcap to Devil's Island and beyond to West Lawrencetown. Fishing is concentrated along the shores and on the many shoals that dot the inlet area.
- Fifteen full time fishermen deploy up to 600 traps in the inner harbour from Ives Knoll to, but not including, MacNab's Cove, from the container port to Hens and Chickens, including the large Point Pleasant Shoal and on the middle ground shoal. These fishermen earn an estimated $15,000.00 per boat. This is a partial income to these fisherman as most are engaged in lobster fisheries elsewhere. Fishing activities in the inner harbour intensify during inclement weather conditions.
- From Purcell's Cove to herring Cove 12 full time fishermen deploy up to 2000 traps and earn from $10,000.00 to $15,000.00 each. This is a rough estimate because most are involved in other nearby fisheries. From Halibut Bay to Sambro Head, including the Litchfield shoal a profitable lobster fishery takes place. Eight or nine fishermen set an undetermined number of traps first in shallow waters along the coast on the last Monday of November (start of fishing season) and then progressively in deeper water further away from shore as the season advances into winter. This fishery yields as much as 400-500 lbs. of lobster per fisherman on the first few days of fishing. The per fisherman partial

income is estimated at $10,000.00.

- Another good lobster fishing area centers around Lighthouse Bank shoal and the southeastern tip of MacNab's Island, but no estimate of numbers of fishermen or income is available.
- A light lobster fishery is reported to exist in Drakes Gut between the southern portion of Lawlor's and MacNab's Islands.
- The most extensive and by far the most important lobster fishing area of the Halifax Inlet extends from Thrumcap Shoal southwest to Never Fail Shoal, southeast to Portugeses Shoal, northeast to Head Rock Shoal and eastward to Devil's Island and West Lawrencetown. This large shallow area is fished actively by 40 fishermen. Although the Department of Fisheries and Oceans has limited data it is estimated that the fishermen involved achieve earnings of $20,000.00 each.

The lobster fishery of the Halifax Inlet represents a small fraction of the total Nova Scotia water's yield as shown in the table below.

Table 1: Comparative Lobster Landings for Some Canadian Waters

Area	**Landings** (metric tonnes)
Easter Canada '88	40,000
Scotia Fundy '87	18,400
Halifax Inlet *(estimated range)*	225-450

Finfish Inner/Outer Harbour

Serious fishing for groundfish (cod, haddock), and pelagic species (herring, mackerel) took place throughout the Harbour in 1989. However in 1994 the cod fishery was closed in all areas. Generally fishing actively intensifies with distance southward. Some fisheries are very short in duration e.g. the Scottish seiners in January, some are seasonal, while others may not occur at all in some years.

- Cod and haddock were the primary species sought in the inner harbour by handlining fishermen (commercial). The catch for the two species combined reached 200lbs. per day. Mackerel is fished occasionally.
- In the outer harbour an excellent cod net fishery took place along the Western Shore from Sandwich Point to Portugese Cove. Nets were set in the summer when fish were present. Although no income data is available, DFO believes this was a viable fishery.
- Also along the Western Shore from Ferguson Cove to Watley;'s Cove and from Litchfield Shoal to Black Point throughout the area there exists a herring net fishery lasting from February to September. This fishery is not monitored but it is reported to be very productive in some years.
- Throughout the outer harbour from Ferguson's Cove to the north and Portugese Cove to the south there existed a seasonal handlining fishery for cod, haddock and mackerel. Approximately nine fishermen were involved in this fishery but information on landings is lacking.
- A significant net fishery for cod, haddock and herring took place in a large area south of Thrumcap Shoal. The area fished extends eastward to devil's Island. The full time fishermen involved in this fishery did not catch their quota (3300lbs./fisherman) and most were engaged in other fisheries.
- A cod fishery also existed in the area between Head Rock Shoal and Portugese Shoal.
- Further to the south and east of Sambro there existed a very successful although short fishery for cod. In the month of January three Scottish seiners, transient vessels from Sambro and Terence Bay were involved in

this fishery.

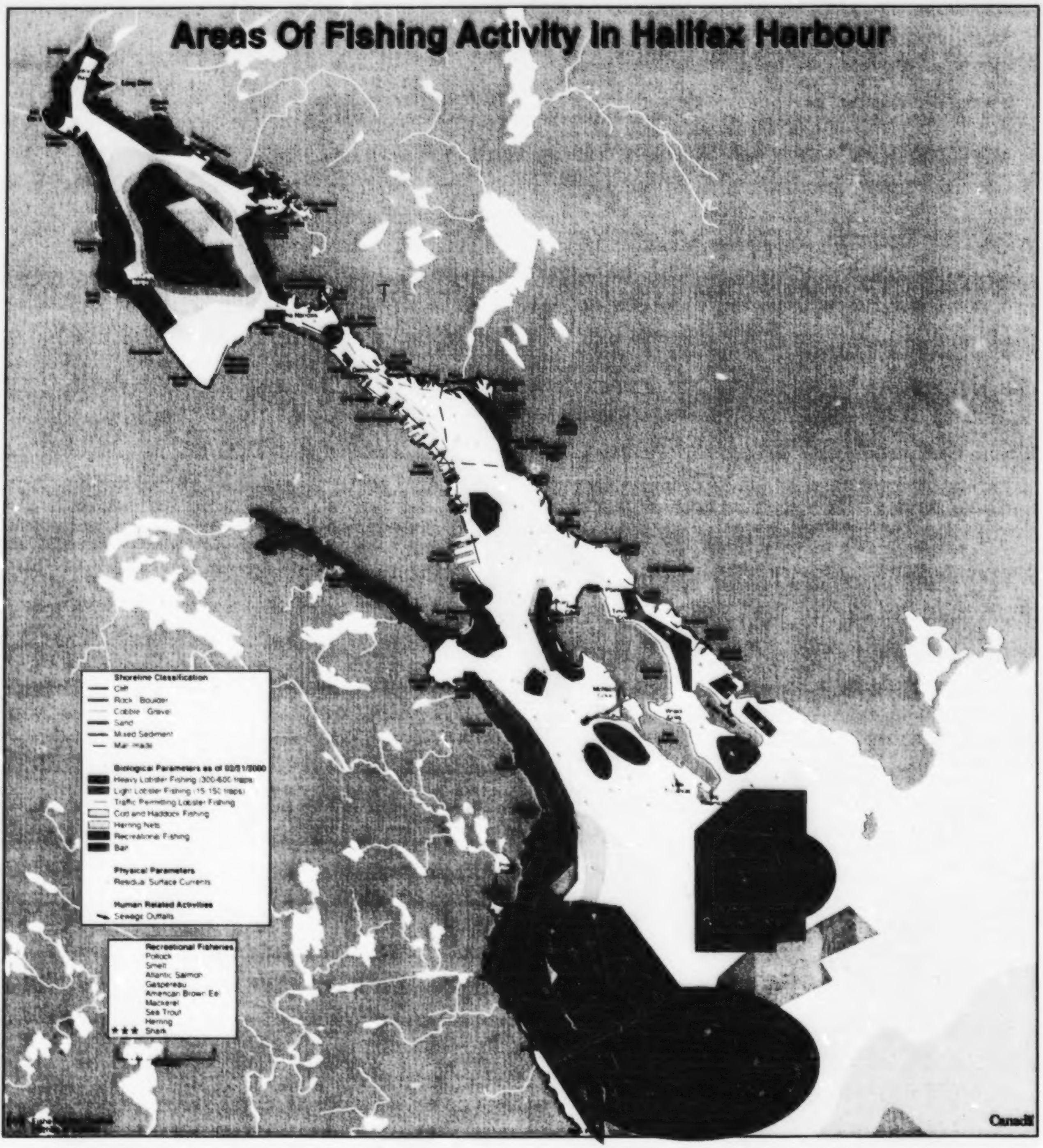
Conclusion

Although a ban on the cod fishery has een in effect since 1994, it is not related to environmental conditions in the harbour. In the event of this ban being lifted, the cod fishery of the harbour may well be resumed.

The Halifax Inlet supports widespread and diversified fisheries for both lobster and finfish. The fishery while representing but a small fraction of the Provincial catch, has sufficiently elevated yield to attract serious full time fishermen for at least a part of their income. The inlet also provides lobster fishermen with a relatively calm work area during inclement coastal weather. Thus to the 70 plus full time fishermen who work the area on a part time or full time basis, the Halifax Inlet is a significant fishing ground.

The principal buyers of all products of fisheries of Halifax Harbour in 1989 were:

Fishermen's Market
Clearwater
Walker's Wharf
Fish Basket
Stan Purcell

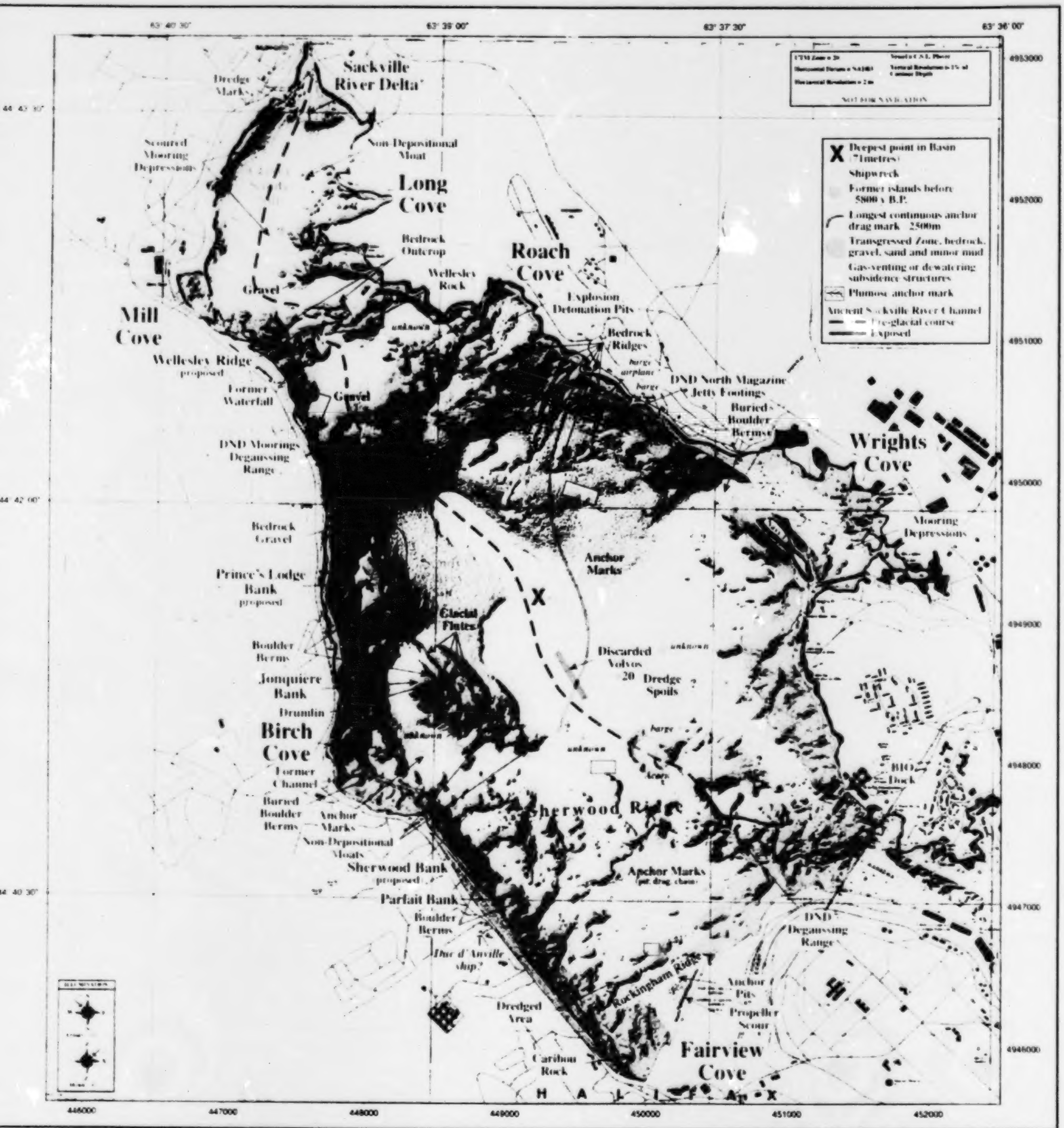


Areas Of Fishing Activity in Halifax Harbour

Poster by Gordon Fader, Robert Miller and Bruce MacGowan

Bedford Basin, Multibeam Bathymetry with Interpretation

BEDFORD BASIN



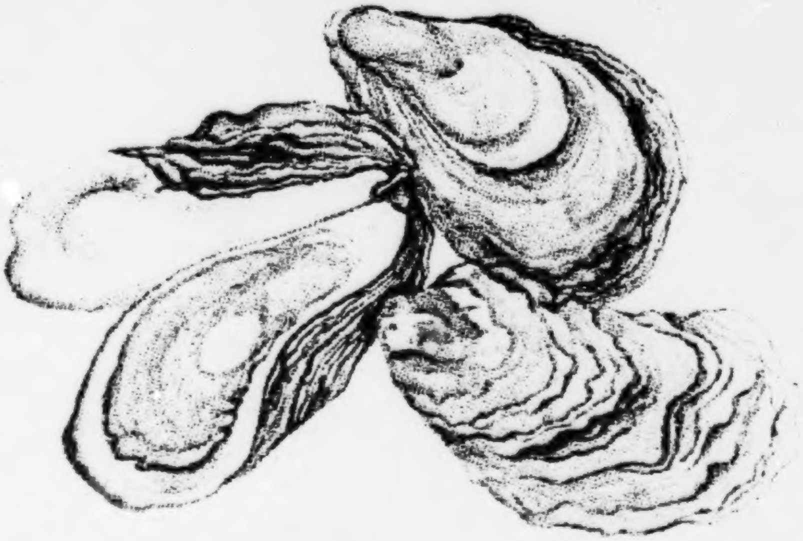
Multibeam Bathymetry with Interpretation

Figure from GSC Open File 3941, 09/2000. Gordon B. J. Fader and R.O. Miller, Geological Survey of Canada,(Atlantic), and Andrew Craft, Canadian Hydrographic Service.

Poster by Roger Percy

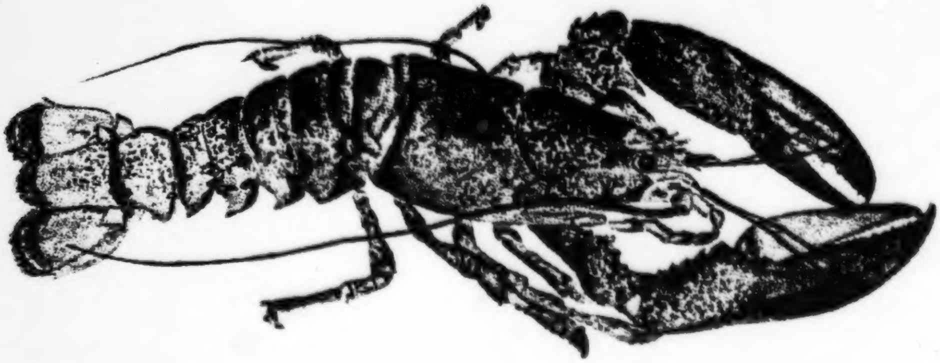
Shoreline Classification and Coastal Resources of Halifax Harbour Area

*** Note: The following figures and tables are reproductions of the insets on the enclosed poster. This was done to ensure readability, since we were limited in the poster size we could include in the Proceedings.



Category:	Aquaculture Site
Type:	Issued
Site#	8312
Product	European Oysters
Location:	Sambro (Nova Scotia)
Company:	
Contact:	Oakley, Edward
Phone:	
County:	Halifax
Source:	NS Dept. of Aquaculture
Latitude:	44.473
Longitude:	63.6102

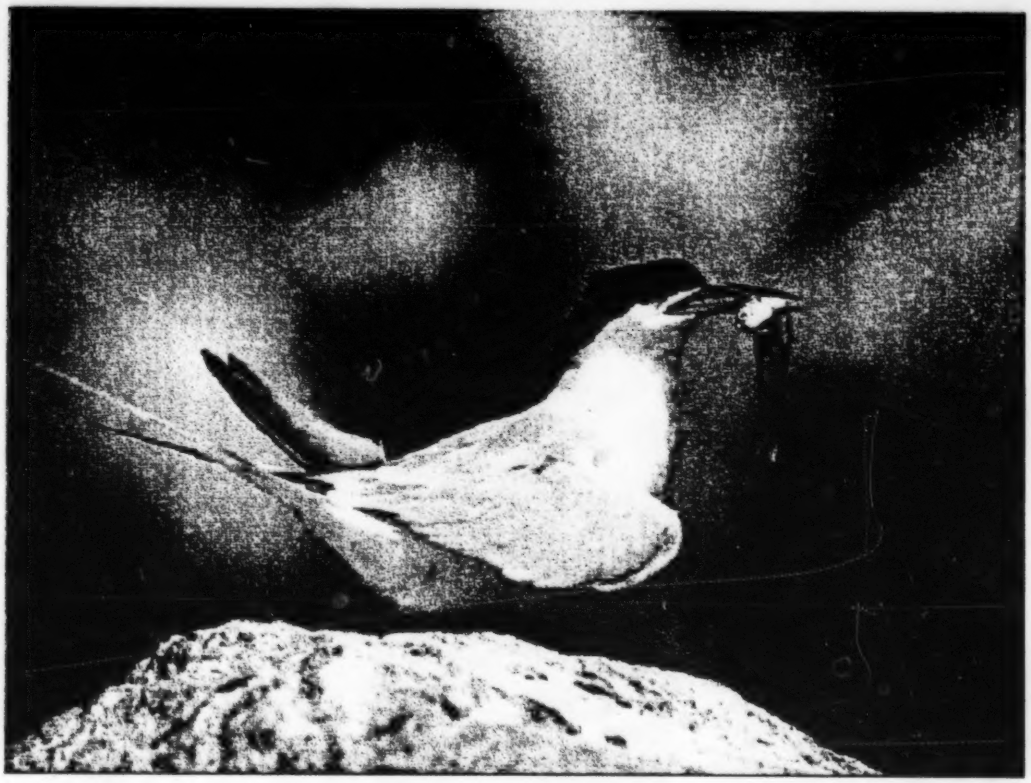
ne



Category: - Crustacean
Specie: - American Lobster
Latin: - Homarus americanus
Distribution: - Halifax Harbour
Spawning: - Lobsters are found on the Continental Shelf from the Strait of Belle Isle to Northern Carolina.
- Eggs hatch May to October with their peak hatching in June and early July.

Habitat: - Occur in depths from 1 m below low tide to 700m in submarine canyons. They live in crevasses and kelp beds and on a combination of coarse substrate and finer substrate for burrowing.

Feeding Habits: - Lobsters are omnivores. They eat crabs, sea urchins, mussels and polychaetes.
Source: - Dept. of Fishieries and Oceans Canada



Category: Coastal Seabird
Specie: Roseate Tern
Latin: Sterna dougallii

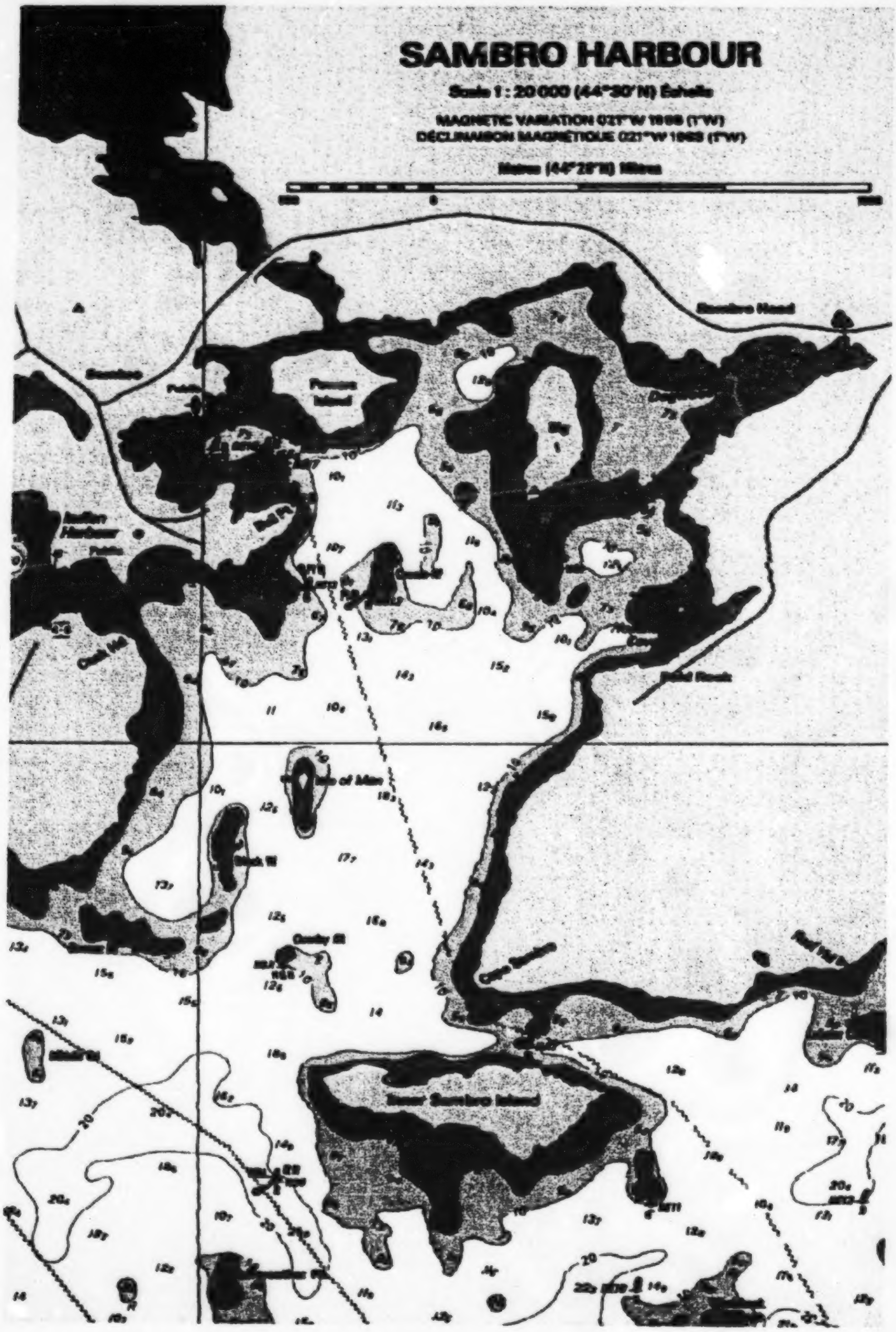
Description:
The Roseate Tern is robin-sized, 35-43 cm. They are white with a black cap; very pale grey back and wings.

Distribution:
The Roseate Tern breeds, in small numbers, in Atlantic Nova Scotia, and in the Bay of Fundy.

Migration/Breeding:
The Roseate Tern is listed as endangered, and breeds in numbers of more than ten pairs in only two sites in Canada.

Habitat:
Roseate Terns inhabit coastal beaches, islands, and inshore waters.

Oil sensitivity:
Terns feed by plunge diving. All species have been decreasing recently, mainly as a result of predation by gulls. They are vulnerable to oiling because of their feeding habits.

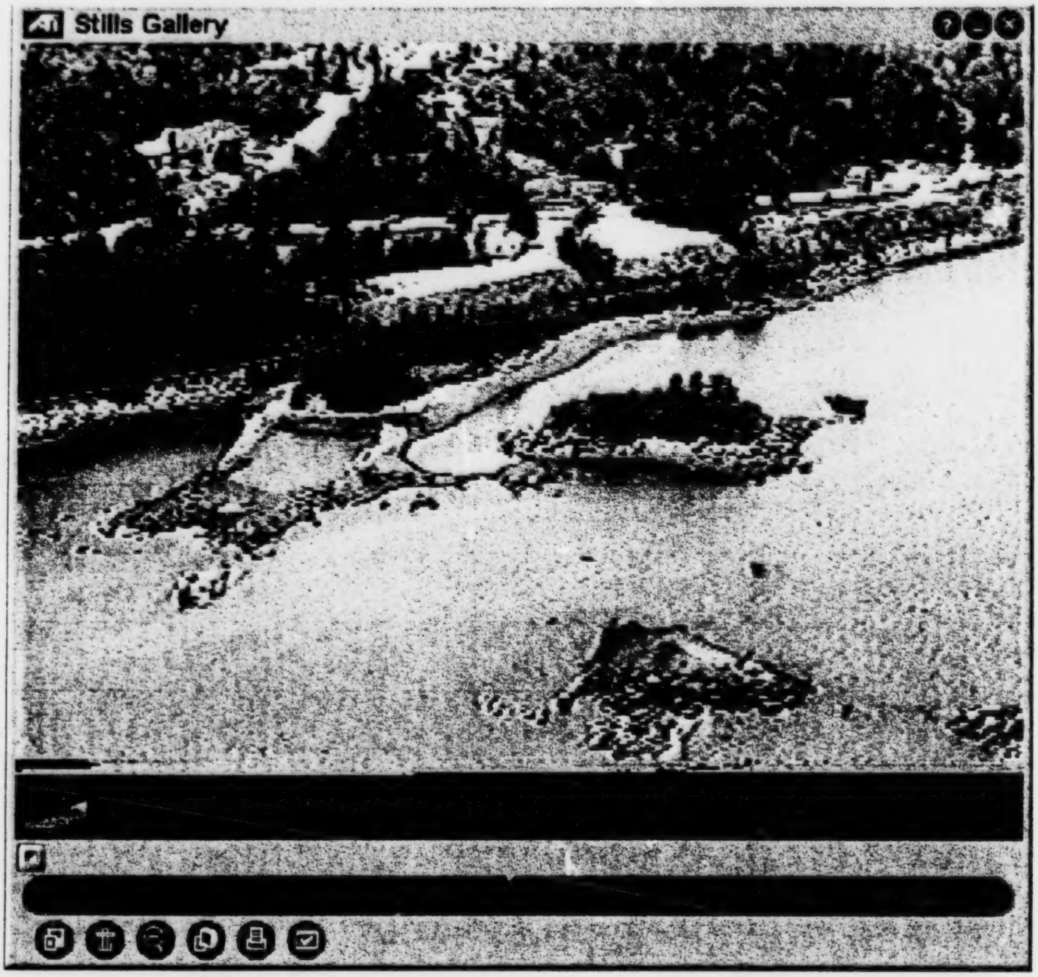

SAMBRO HARBOUR
Scale 1 : 20 000 (44°30'N) Échelle
MAGNETIC VARIATION 021°W 1988 (1'W)
DÉCLINAISON MAGNÉTIQUE 021°W 1988 (1'W)
Indian Harbour
Isle of Man
Black Rock
Lower Sambro Island

EASTERN PASSAGE,
NOVA SCOTIA

Category:	Small Craft Harbour
Name:	Eastern Passage
Description:	unknown
Location:	Halifax Harbour
Sub Region:	Scotia-Fundy
Photo:	Eastern Passage.JPG

SCH Region:	Scotia-Fundy	Water:	False
Province:	NS	Navigation beacon:	False
Map reference:	M20	Fuel (gasoline):	False
Ice:	True	Power (220v):	True
Lights:	True	Ramp:	True
Fuel (diesel):	True	Hauling winch:	True
Power (110v):	True	Authority DFO:	True

Source: DFO Canada - Small Craft Harbours, Moncton, NB



Category:	Aerial video survey
Tape#:	7
Segment#:	57
Segment name:	Halifax Harbour - Herring Cove to CFB Halifax
Source:	R.B Taylor & D. Frobel, Geological Survey of Canada, Dartmouth, NS

SHORE ZONE CHARACTER

REGION :ATL-4 **SEGMENT : HX-75**

SEGMENT LENGTH : **1.4 km**

SHORELINE MATERIAL/TYPE :

Lower ITZ material : **bedrock resistant**
Lower ITZ type : **platform**
Shoreline type : **bedrock**
Backshore material : **bedrock resistant**
Backshore type : **platform**

Permanent inlet :
Inlet location changes :
Inlet width :
Cyclical inlet :
Inlet shape changes :
Number of channels :

NEARSHORE ENVIRONMENT :

Tidal range : Mean tide **1.5 (m)** Large tide **2.1 (m)**
Open, exposed coast ? **Yes**

PREDOMINANT LONGSHORE CURRENT/DRIFT DIRECTION: **?**

OIL TRAPS AND POTENTIAL BEHAVIOUR :

Natural alongshore barrier (e.g. headland) **No**
Man-made alongshore barrier (e.g. wharf) **No**
Pebble/cobble - penetration potential **No**
Bay or re-entrant **No**
Riprap or boulder - reservoir potential **No**
Marsh meadow oiling potential during high water levels **No**
Sand/gravel - burial potential **No**
Overwash potential into lagoon/marsh **No**
Tidal lagoon or estuary **No**
Tidal inlet or channel **No**

RESOURCES AT RISK :

Birds (shore birds, ducks) **No**
Crustaceans or Mollusks **No**
Fish (nearshore only) **No**
Flora/Plant communities **No**
Mammals (marine) **No**
Agricultural **No**
Commercial or Industrial **No**
Harbour or Marina **No**
Recreation **No**
Residential **No**

Primary resources: **AESTH: scenic lookout**

Secondary resources:

Is the segment within a PAR ? **Yes**

INFORMATION SOURCES :

Topographic Map(s): 11 D/11
Hydrographic chart(s) : 4237
Videotape(s): GSC Open File # , Seg #58 (1989)
Aerial photographs:
References: 1, 2, 3, 4, 5

SHORELINE PROTECTION

REGION: ATL-4 **SEGMENT: HX-75**

PROTECTION - OBJECTIVE(S)

(1) Prevent contact with shore or resource(s) at risk within the segment	**No**
(2) Minimize degree of contact with shore or resource(s) at risk	**Yes**
(3) Prevent contact with shore or resource(s) at risk in adjacent segment(s)	**No**
(4) Contain stranded oil at the shoreline	**No**
(5) Prevent oil transport into inlet, estuary, or channel	**No**

PROTECTION - STRATEGY(IES)

(1) Alter direction of transport or movement of oil on water	**Yes**
(2) Prevent oil movement in channel(s) on flooding tides	**No**
(3) Trap or contain and collect oil at shoreline	**No**
(4) Prevent overwash into backshore or lagoon	**No**
(5) Pre-impact shoreline debris removal	**No**

PROTECTION - METHODS

P1	Nearshore (on-water) containment and recovery	**R**
P2	Nearshore redirection away from shore / recovery	**O**
P3	Nearshore redirection towards shoreline containment / recovery	**NR**
P4	Exclusion booming	**I**
P5	Shoreline protection intertidal booming / recovery	**I**
P6	Shoreline barrier or berms/sumps and recovery	**I**
P7	Contact barriers	**I**
P8	Channel boom or barriers / recovery	**I**

R=Recommended O=Optional or Possible I=Impractical NR= Not Recommended

PROTECTION - OPERATIONAL CONSIDERATIONS

Nearshore access affected by shoals or reefs/rocks ?	**Yes**
Direct backshore or alongshore access ?	**No**
Coast exposed to storm and/or winter wave action ?	**Yes**
Strong currents (> 1 knot: 0.5 m/s) ?	**No**
Winter ice on water and/or on shore ?	**No**

SHORELINE TREATMENT

REGION : ATL-4 **SEGMENT : HX-75**

SHORELINE TREATMENT/CLEANUP - OBJECTIVE(S)

(1) Allow oiled shore zone to recover naturally	No
(2) Restore oiled shore zone to pre-spill condition	No
(3) Accelerate natural recovery	Yes
(4) Restore with minimal material removal	Yes
(5) Minimize remobilization of stranded oil	Yes
(6) Minimize operational damage to dune, marsh, or peat bog system	No

SHORELINE TREATMENT/CLEANUP - STRATEGY(IES)

(1) Monitor	No
(2) Act quickly to remove oil before it is reworked and/or buried	No
(3) Remove bulk oil - allow residue to degrade	Yes
(4) Minimize waste generation by in-situ techniques	Yes
(5) Manual treatment techniques preferred	No
(6) Salt-marsh fringe or backshore treatment strategy	No
(7) Backshore riprap treatment techniques	No

SHORELINE TREATMENT/CLEANUP - METHODS

S1 Natural recovery	R	S11 Mechanical recovery	I
S2 Flooding	O	S12 Vegetation removal/Cropping	O
S3 Low-pressure, cold water wash	O	S13 Passive sorbents	R*
S4 Low-pressure, warm water wash	O	S14 Tilling /Aeration	I
S5 High-pressure, cold water wash	O	S15 Surf washing/Sed. reworking	I
S6 High-pressure, warm water wash	NR	S16 Burning	I
S7 Steam cleaning	NR	S17 Dispersants	O
S8 Sandblasting	NR	S18 Shoreline cleaners	O
S9 Manual removal	R*	S19 Solidifers	O
S10 Vacuum recovery	O	S20 Bioremediation	O

R=Recommended (* for small amounts of oil) O=Optional/Possible I=Impractical NR=Not Recommended

SHORELINE TREATMENT/CLEANUP - OPERATIONAL CONSIDERATIONS

Remote area ?	Y	Road access ?	N
Nearshore shoals, shallow water ?	Y	Alongshore access possible ?	N
High tidal range (> 3m) ?	N	Staging area available nearby ?	N
Narrow intertidal width ?	?	Shore zone suitable for machinery ?	N
Winter on-shore ice ?	N	Backshore cliff present ?	N

SUMMARY OF RESPONSE REQUIREMENTS

REGION: ATL-4 **SEGMENT:** HX-75

RESPONSE PRIORITY: L

PRIMARY RESOURCES: AESTH: scenic lookout

PROTECTION RESOURCE REQUIREMENTS:

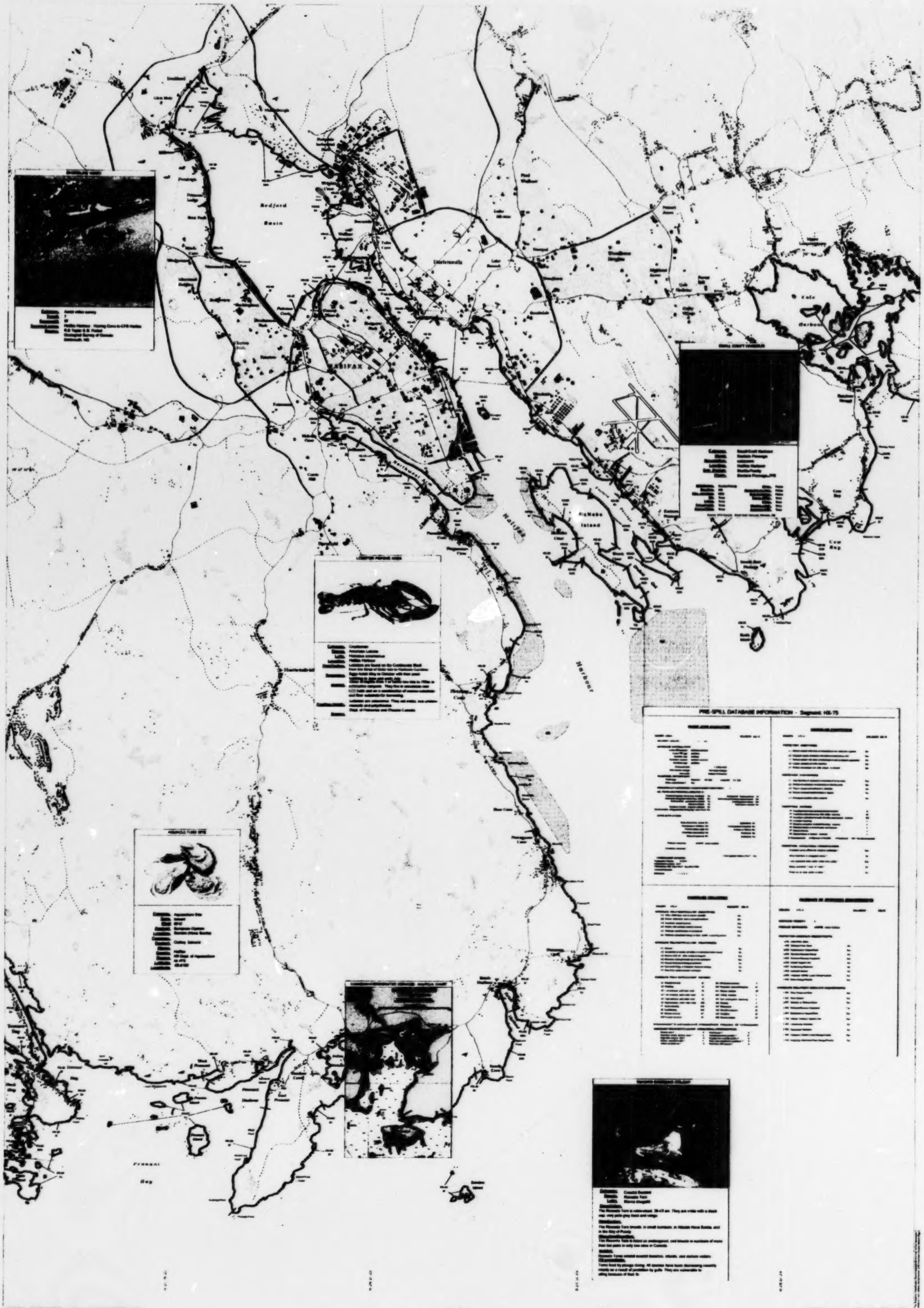
LP01: Open-Water Boom	
LP02: Sheltered-Water Boom	No
LP03: Deployment or Support Boats	Yes
LP04: Shoreline (Intertidal Boom)	No
LP05: Skimmers/Recovery Equipment	Yes
LP06: Manual Support Crew	No
LP07: Earthmoving Machinery	No
LP08: Geotextile Barriers	No
LP09: Temporary Oil/Oily Liquid Storage/Transfer	Yes
LP10: Debris Storage/Transfer	Yes

SHORELINE TREATMENT RESOURCE REQUIREMENTS:

LT01: Water Pumps and Hoses	Yes
LT02: Water Heaters	Yes
LT03: Shoreline or Sheltered Boom	Yes
LT04: Skimmers/Recovery Equipment	Yes
LT05: Deployment or Support Boats	Yes
LT06: Manual Cleanup or Support Crew	Yes
LT07: Earthmoving Machinery	No
LT08: Agricultural Machinery	No
LT09: Temporary Oil/Oily Liquid Storage/Transfer	Yes
LT10: Temporary Oiled Solid Waste Storage/Transfer	No

REET - Atlantic Region
Sensitivity Mapping Program

Shoreline Classification and Coastal Resources Mapping Program



PRE-SPILL DATABASE INFORMATION - Segment: HX-75

[illegible]

RF 1:30 000

Kilometres

Latitude/Longitude NAD83

Bird Distribution
- Coastal Seabird
- Pelagic Seabird
- Shorebird

Lobster Fishing Area
Lobster fishing (heavy)

Extraction Sites
Aquaculture Site

Sensitive Areas
- Environmentally Sensitive Area
- Provincial Park (point)
- Historical Site
- Wildlife Conservation Area
- Provincial Park (area)

Recreation Sites
- Small Craft Harbour
- Recreational Beach
- Scuba Diving Site
- Marina

SHORELINE CLASSIFICATION

Shoreline Type (Upper Intertidal Zone)
- Bedrock (1a)
- Man-made solid (1b)
- Boulder beach (2f)
- Pebble-cobble beach (2d/e)
- Mixed sand-gravel beach (2c/d)
- Sand beach (2c)
- Sand tidal flat (2b)
- Mud tidal flat (2a)
- Salt marsh (3a)
- Shoreline classification boundary
- Segment label lines
- Segment boundary

Hydrography and Marine

Transportation and Boundaries

Buildings, Recreation and Points of Interest

Oil Handling Facilities

Built Up Areas and Vegetation

[illegible]

The Maritime Provinces

Appendices

Appendix A

Preserving the Environment of Halifax Harbour
Workshop # 2 March 14th – 15th 2001

Location: Main Auditorium, BIO, 1 Challenger Drive, Dartmouth, N.S.
Sponsors: DFO and Halifax Regional Municipality (The Harbour Solutions Project)

(A gathering of stake-holders from three levels of government, academia, industry, and public interest groups to: review the state of environmental knowledge in Halifax Harbour, identify information gaps in the light of future large developments, and identify required actions for the preservation and restoration of fish and wildlife habitats and aesthetic values in Halifax Harbour.)

Agenda
Wednesday March 14th

07:45 **Registration** *(Name tags and registration packages)*
Debi Campbell, Oceans & Coastal Management Division, DFO

08:15 **Opening Welcome from BIO**
Jacob Verhoef, Director, Geological Survey of Canada (Atlantic), NRCan

08:30 **DFO's Aspirations for Fish Habitat in Halifax Harbour: Realities and Opportunities**
Jim Ross, Biologist, Habitat Management Division, DFO

09:00 **Objectives of Workshop #2**
Brian Nicholls, Workshop Chair, DFO – retired

Part 1 – The State of Environmental Knowledge

09:25 **Highlights of previous Workshops on Halifax Harbour (1989…)**
Don Lawrence, Research Scientist, Science Branch, DFO

09:55 **Coffee Break**

10:10 **Historical Perspective of Metal Contaminants in Halifax Harbour**
Dale Buckley, Emeritus Scientist, NRCan
Contaminants in Halifax Harbour
Phil Yeats, Scientist, Marine Chemistry Section, DFO
N.B. Time slot to be shared. Buckley speaks to sediments and Yeats speaks to water column

11:00 **Halifax Harbour: The Geology and Evolution of Marine Habitat**
Gordon Fader, Scientist, Geological Survey of Canada, NRCan

11:30 **The Fish Fauna of the Harbour**
Andrew Hebda, Curator, Nova Scotia Museum of Natural History

12:00 **The Benthic Fauna**
Don Peer, Scientist, DFO - retired
Presented by Susan Belford, Consultant, Jacques Whitford

12:30 **Lunch** *(BIO Cafeteria catered)*

13:30 **Other Wildlife and Their Habitats**
Tony Lock, Scientist, Environment Canada

Part 2 – Spectrum of Harbour Activities

14:00 **Major Development Projects of the Past**
Alan Ruffman, Consultant, Geo-marine Associates

14:30 **Cumulative Infilling Activities**
Clarence Spencer, Scientist, Environment Canada

15:00 **Coffee Break**

15:15 **Major Future Development Projects**
Bill Campbell, Director, Halifax Waterfront Development Board
David Bellefontaine, Director, Port Authority
N.B. This time slot to be shared by the two above speakers

Part 3 – Measurable Impacts on Fish Habitat

16:05 **Changes/Degradation of Benthic Habitats**
Annamarie and Bruce Hatcher, Dalhousie / Canfish

16:50 **Changes in Planktonic Microbiota**
Bill Li, Research Scientist, Science Branch, DFO

17:20 **End of Day One**

Thursday March 15th

08:15 **Summation of Available Knowledge: What else do we need to know?**
Ken Mann, Scientist Emeritus, DFO

Part 4 – Achievable goals

08:45 **Halifax Harbour Solutions Project: Update**
Tony Blouin, Assistant Director, Halifax Harbour Solutions Project

09:15 **The Hamilton Harbour Case: Lessons learned**
Victor Cairn, Resource Manager, DFO (Hamilton, Ontario)

09:45 **Eliminating Sources of Contaminants**
Roger Percy, Scientist, Environment Canada

10:10 **Coffee Break**

10:20 **Pollution Source Control**
John Sibbald, HRM, Environmental Services and Engineering Approvals

10:45 **Community Perspective on Preserving the Environment of Halifax Harbour**
Patricia Manuel, Professor, Nova Scotia College of Arts and Design

11:15 **HRM Activities pertaining to the Aesthetic Value of Halifax Harbour**
Simpson McLeod, HRM Planning Dept. - Retired

11:40 **DFO on Recovering Lost Habitats**
Bob Rutherford, Biologist, Oceans & Coastal Management Division,DFO

12:05 **Summary of Workshop # 1 Recommendations**
Brian Nicholls, Workshop Chair, DFO - retired

12:30 **Working Lunch** *(BIO Cafeteria Catered)*

Part 5 – Workshop: Developing Recommendations

N.B. The participants will be divided into reasonably sized equal groups and, with the help of pre-named facilitators they will be asked to work at elaborating a statement or Motto encompassing a vision for the future for Halifax Harbour. One or several of these will subsequently be adopted by the workshop as the recommended vision for the preservation of the environment of Halifax Harbour. In addition they will elaborate several realistic recommendations aimed at addressing: 1) the knowledge gaps identified; 2) abating or containing contamination sources; 3) preserving existing habitats; and, 4) enhancing aesthetic and other values of Halifax Harbour.

14:00	**Group Reports and recommendations to Plenary Session**
15:00	**Coffee Break**
15:15	**Development and Approval of Workshop Final Recommendations to DFO, HRM and other Agencies.**
16:15	**Closing Remarks** *(and drawing of Door Prize - Nova Scotia Crystal)* *Brian Nicholls, Workshop Chair, DFO - retired*
16:30	**End of Workshop**

Posters Presentations

The Fisheries of Halifax Harbour	Andre Ducharme Paul Rozee
Bedford Basin, Nova Scotia: An Interpretation of Seabed Materials, Features and Processes on Multibeam Bathymetry	Gordon Fader Robert Miller Bruce MacGowan
Environmental quality assessment of Halifax Harbour: Geological and Geo-chemical Perspective	Dale Buckley
Lost Freshwater Habitat	Jennifer Bruin
Chlorobiphenyls from a non-Aroclor source: Where do they come from?	T.King P. Yeats J. Hellou S. Niven
Low molecular weight non-ortho chlorobiphenyls in mussels collected in and around Halifax Harbour	T.King J. Hellou V. Kitko
Levels and source apportionment of polycyclic aromatic hydrocarbons (PAHs) and sulphur heterocycles (PASHs) in sediments and mussels	J. Hellou T.King J. Leonard T. Milligan S. Stellar P. Yeats V. Zitko
Shoreline Classification and Coastal Resources of Halifax Harbour Area	Roger Percy

Appendix B

Group Reports

Rapporteur, Dr. Cathy Conrad

Group 1

The discussion focussed on drafting a vision statement, followed by a series of recommendations to fill knowledge gaps, to abate contamination sources, and to enhance the aesthetics of Halifax Harbour.

"Motto"

Rather than drafting a lengthy vision statement, the group decided that a brief and concise motto for the Halifax Harbour would be appropriate. The proposed motto is:

"Bringing Life Back to the Harbour"

Bringing because this is underway, and *Life*, in all of its forms. Life is meant to represent *People*, in terms of their renewed interest in the Harbour and harbourfront, in particular. With renewed interest, more individuals will want to live and recreate in and near the harbour environment. By abating contamination and enhancing aesthetics, tourists will also be enticed to visit the harbour's environment. Naturally, the group also implied that *Fish, Plants,* and *Habitats* are included in the *Life* which will be brought back to the harbour.

Main Recommendations

The group discussed recommendations for filling existing knowledge gaps, such as;

1. A habitat inventory of the Halifax Harbour Inlet Ecosystem.

Habitat mapping of the Harbour would serve to provide stakeholders with knowledge of the extent and quality of the Harbour's various ecosystems. An understanding of the health of biological communities would work towards the goal of setting aside, preserving, and perhaps recreating habitat. In order to preserve existing habitats, the group discussed a second recommendation;

2. To utilize usage zoning as a habitat management tool.

Zones for specific harbour uses should be set in place. The group acknowledged that this may be difficult in some areas of the Harbour, but that it should be initially done for some areas of the Harbour, at the very least. The result would be protected habitats and improved aesthetics. Successes in Hamilton Harbour and in the Great Barrier Reef were used as good examples of what we might try to strive towards in our environment.

It was quickly acknowledged that it will be difficult to bring all stakeholders together and to "get things done", and therefore our third recommendation was to;

3. Establish an independently co-ordinated, jointly funded group, whose purpose is to:
   - Gather, digest, disseminate and consolidate information
   - Consolidate stakeholders
   - Generate habitat quality goals, and
   - Develop an Action Plan.

This group will be vital in seeing the process through from start to finish. Although the group agreed that this is a very important recommendation, in terms of "getting things done", we did not discuss exactly who would or should take on this responsibility. A further recommendation, however, was that;

1. The provincial government (DOEL) should be involved.

In addition to the strong presence from HRM and from DFO, the provincial government needs to and should be equally committed and involved. Our final recommendation, also regarding involvement, was to;

2. Set up a mechanism for community-based monitoring.

The group was comprised of Toby Balch (representing the community), Tony Blouin (HRM), Annamarie Hatcher (Dalhousie University), Kim Seto (DFO) and Cathy Conrad (Saint Mary's University), who acted as Rapporteur and presented the findings of the group to the plenary.

Rapporteur, Betty Ann Aaboe-Milligan

Group 2

The discussion centered around fulfilling the request of the conference organizers to provide a vision for the future of Halifax Harbour with realistic recommendations to address 1) knowledge gaps; 2) abating or containing contamination sources; 3) preserving existing habitats; and 4) enhancing aesthetic and other values of Halifax Harbour.

The group discussed;
a) the uselessness of motherhood statements without concrete plans for action and,
b) the limit of what could be done by this group in the one hour allotted.

The group felt that the search for recommendations could be reflected in four words: Protection,Prevention, Remediation and Research. With this in mind a vision and goals were drafted.

Vision

" To achieve a continual improvement to the aesthetic, ecological and human health aspects associated with the Halifax Harbour System"

Of concern to the group was the definition of Halifax Harbour. It was discussed that three watersheds fed the harbour. In considering the health of the Harbour we also had to consider the health of the watersheds. For this reason it was decided that the vision statement should include the word 'system' so that it would truly reflect the water systems and land mass which impacted upon the Harbour. The baseline from which improvement would be measured was also of concern . For this reason it was felt that it was important to express the need for 'continual ' improvement so as to reflect a never ending process of betterment.

The three aspects of the vision are aesthetic health, ecological health and human health. To each aspect we applied the words:
protection/prevention-regulatory action
remediation-plantings, green space etc.
research- eg: offshore monitoring and attempted to determine what actions were required in each case. The result was the creation of several goals.

Goal 1

Improvement in the aesthetics of the Halifax Harbour system through a 50% reduction of floatables, turbidity and odours.

It was felt that a body of knowledge already existed on the topic and that there were known methods for improvement. What was required was action.

Goal 2

Any water system should separate surface drainage from waste water discharges

At issue was the problem of 'reduction at source'. The example discussed was the combination of sewage and storm sewers along the Harbour . This brought forth a discussion of the limits of financial and regulatory resources to accomplish this. DFO has systems, HRM has rules. Working together is necessary. It was also considered that there needed to be ways of limiting contamination of the surface drainage.

Goal 3

Consistent with industrial development, to optimize the macrophyte habitats of the Halifax Harbour system.

A discussion followed as to what 'near shore' implied and included. The term 'optimize' was intended to include protection and research

Goal 4

Reduction of pathogens(e.g.: virus) and toxins (e.g.:metals)

This goal was seen to result in the potential of the potential of the harbour to provide foodstuff and recreational facility

As time became limited, so was the discussion.

The group was comprised of Betty Ann Aaboe-Milligan, Dale Buckley, Dave Jamieson, Ken Mann, John Sibbald and Nancy Weatherspoon

Rapporteur, Jim Ross

Group 3

Participants: Donald Burns
Victor Cairns
Marianne Feetham
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Patricia Manual
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A vision for the harbour
The group focussed on the elements that should be encompassed by a vision statement of the future of Halifax Harbour rather than developing a vision statement itself. They are in no particular order:

- The future harbour should be something of which future generations will be proud;
- Human health and safety issues should figure prominently;
- Aesthetic aspects must be considered;
- A biologically healthy ecosystem should be encompassed in the vision;
- Continuous incremental improvements in the health of the harbour should be taken as a given;
- Any vision developed for the harbour must apply equally/consistently to all areas of the harbour.

The group was unanimous that there must be a political will created. This will must be built by the community to provide political decision-makers with the justifications to make the necessary decisions to attain a shared vision for the harbour.

Recommendations:
The group believes that it is very important to get this project off the ground as soon as possible. Therefore, they presented only one recommendation directed to this.

To help accomplish this it is important to have a collaborative management process started as soon as possible. The process should be lead by the Halifax Regional Municipality, as they appear to have the broad mandate appropriate to lead this. There was some division in the group as to whether the process should be facilitated by an independent third party, or be lead by a full time, dedicated, project manager. The example of the project manager hired for the Hamilton Harbour project was cited as an example. The rational for a collaborative process is best stated by a member of the group: "everyone needs to feel they have input" to the process.

The majority thought that the first piece of business in establishing a collaborative process should be a workshop with a wide representation of stakeholders to:

- develop a vision based on a larger constituency
- develop a group to look at larger issues other than sewage related ones

The vision of the harbour should encompass the larger harbour, or watersheds, that contribute to harbour inputs.

Rapporteur – S.Kempton

Group 4

HALIFAX HARBOUR VISION

"A healthy, attractive, accessible and productive harbour environment in which present and future generations can accommodate multiple uses in a sustainable manner."

KNOWLEDGE GAPS

- A comprehensive understanding and description of the Halifax Harbour environment (including its watershed) is required.
- A database/bibliography should be created to encompass areas such as, but not limited to, the following:
  - oceanography (biological, physical, chemical)
  - geology
  - geography (physical, human)
  - socio-economic
- Legal – a complete knowledge of the various legal regimes that govern/impact upon the harbour environment, the resources required to ensure their effective enforcement, and identification of overlaps and gaps in the regimes
- Developing current and accurate means of modelling to permit reasonable prediction/evaluation of projects/changes/evolution in the harbour environment

CONTAMINATION SOURCES

- Need to identify/develop key indicators of harbour health
- Require a definition of what is "safe"
- More rigorous monitoring of inputs into harbour, both land and marine-based sources

PRESERVING/ENHANCING EXISTING HABITATS

- Adopt precautionary/ecosystem approach to managing the Halifax Harbour environment
- Identify and establish protected areas and areas designated for single/multiple use (i.e. industrial/commercial, residential, common/recreational, exclusion zones, etc.)

- Planning/evaluation of projects (e.g. development) cannot be done in isolation. Must be able to look at cumulative effects of a single project when added to other projects in the whole harbour environment
- Effective conflict resolution means required – part of the planning process, some conflicts can be avoided through effective zoning regulations (protected areas, other designated use areas)
- Old City dump requires a solution to mitigate/eliminate leaching into harbour

ENHANCING THE AESTHETIC AND OTHER VALUES OF HALIFAX HARBOUR

- maintain/enhance historic character of city – preserve Citadel sightlines, preserve/re-create historic buildings/sites
- improve accessibility/common areas of waterfront
- "greening" of the waterfront/downtown core

WHERE DO WE GO FROM HERE?

- Develop and integrated planning process and plan for Halifax Harbour (city, port, environment all interconnected)
- Planning and review is a continuous process
- What is the crisis? What issues do we use to stimulate public (and private) interest and participation?
- Identify and bring in champions to develop and maintain political will and participation, and momentum
- If DFO and partners are developing integrated management processes and plans for other areas of the marine habitat, why not Halifax Harbour? Apply the Oceans Act.

Rapporteur, Darria A. Langill

Group 5

Al Chaddock, Gordon Fader, Willy Gelvan, Rosalee Grette Lydon, Phil Yeats

The discussions centred around the four main themes suggested in the program: 1) the knowledge gaps identified; 2) abating or containing contamination sources; 3) preserving existing habitats; and 4) enhancing aesthetic and other values of Halifax Harbour.

Knowledge Gaps

The group identified several knowledge gaps. Both the systematic study of contaminants and the organized assessment/ description of the benthic community are not detailed enough to provide necessary answers to current questions. The equipment is now available to provide an assessment of the littoral and sublittoral zone and classification of shorelines. These address the question of what is there and provide a baseline for the next question, "What is needed to be known for the health and progress of a watershed management plan?". This begs the questions "what biological indicators are present" and "how are they being monitored so that they may be used as a decision tool in the management of the resource". The need to improve the physical models that can predict the impact of issues such as wind pattern changes due to urbanization and the effect on water currents also need to be addressed.

Abating or Containing Contamination Sources

Diversion of storm water from sanitary flow on a "sewershed" basis was the first item stressed in importance. Following this was the inputs to sewer and reduction at source need for sewer flow. However, a monitoring component was considered essential to verify improvements. The need for monitoring and effective enforcement was key to this discussion with a one on one consultation component to be used as a management tool. The group also felt a need to recognize that deposits/sediments will remain and exist in the harbour as a potential source of future contamination and therefore creates a need to minimize their disturbance. Additionally, the delineation of hotspots requires monitoring.

Preserving Existing Habitats

The question of preserving all existing habitats was discussed at length with the view that non-native habitats may not serve the harbour health best by being preserved. The question must be answered whether all habitat involved is "good" habitat. The need to recover biologically productive habitat was seen as a much greater need, especially as the harbour starts to restore itself. Preserving existing habitat was not seen as the goal, however, promoting the natural recolonization of the environment was. The goal statement that evolved from this discussion was to promote shoreline and watershed remediation that encourages biodiversity and species richness.

Enhancing Aesthetic and Other Values of Halifax Harbour

This group was running out of time and did not discuss the fourth topic at great length. A need to stop the straightening of shoreline and redesign alignment and slope was discussed. The essential natural environment rejuvenation was seen as a goal. The Hamilton Basin example could be viewed as a model, keeping in mind that each area is unique and what works in one spot may not be feasible in another do to differences in weather conditions, different habitat, and different targeted species. The need for community involvement and the promotion of the people was key to the stewardship approach.

In Addition

The group was in agreement that more attention should be made to the watershed as a management unit so that the governance is in accordance with regulatory agencies. The need to identify the process of how collaborative management of a watershed is achieved was paramount. A neutral party is required to co-ordinate the efforts of a watershed management plan for the Halifax Harbour and make the plan work. The group motto was "A healthy harbour is an investment in the future, not a cost".

The group was comprised of Al Chaddock, Gordon Fader, Willy Gelvan, Rosalee Grette Lydon, Phil Yeats, and Darria Langill who acted as Rapporteur and presented the findings of the group to the plenary.

Rapporteur: Sara Hollett

Group 6

The group was comprised of Susan Belford, John Charles, Ted, Marjorie, and ?. Most of the discussion focused on the possible reasons why there has been no clear solution proposed for the management of Halifax Harbour. Our objective was to develop a vision statement for the future of the harbour, identify the gaps that exist at present, and offer recommendations for closing these gaps. It was unanimously agreed that an integrated approach is necessary because of the many components of the harbour ecosystem and the many interests in its use.

Vision

The vision that was agreed upon was the vision that had been chosen at the 2000 workshop.

"Ecological integrity of the greater Halifax Harbour
ecosystem including its present human population"

This was statement represents a goal for all stakeholders to share and work toward. It encompasses the greater harbour ecosystem including the watersheds, islands and its full expanse along the coastline. There was some discussion as to what "ecological integrity" might mean exactly, and this would have to be discussed further before the vision be adopted this year.

Gaps

1. There is a **knowledge** gap between what is known about the Halifax Harbour ecosystem and what needs to be known for effective management.
2. There is **a resource** gap between what funds and human resources are allocated to working on harbour preservation and what is needed for effective management.
3. There is a gap in **will**, i.e., it doesn't seem that any regulatory bodies are dedicated to taking a leading role in preserving the harbour ecosystem, and that many citizens are apathetic toward how their activities affect the ecosystem and are unwilling to be proactive.

Recommendations

1. **Report on the Ecosystem Integrity of Halifax Harbour.** This would be a collection of data that would illustrate the present situation of the harbour. This would address the "knowledge gap" by providing a baseline from which to decide what is needed to preserve and/or improve the environment.
2. **Social Science Database.** This would also address the knowledge gap by providing information on who has interests in the Halifax Harbour and what is valued to them.
3. **Halifax Harbour Advisory Board.** This was the recommendation that generated the most discussion and approval. In order to achieve an integrated management plan, this board must involve all interested parties, which is, essentially, everyone. Representatives from the Halifax Port Authority, DFO, HRM,

regulatory bodies, Waterfront Development Corporation, NGOs, and community members would need to have input.

4. **Establish Responsibility and Mandate.** An integrated management plan requires strong leadership. It was said that DFO has not taken the initiative even though it is the body with jurisdiction to do so. It has a bigger mandate and not enough resources to take on the responsibility of preserving the harbour. Therefore, a body with adequate resources and interest in the harbour is needed to take on the leading role. It was suggested that this should be HRM, but it would need support from DFO for the "science" part.
5. **Empower HRM.** Along with the previous recommendation, it was noted that HRM, at present, does not have legal jurisdiction over the harbour waters, and that has made it difficult for it to take a leadership role. Although transferring jurisdiction is next to impossible, it was suggested that establishing a memorandum of understanding with the Federal Government would be possible.
6. **Utilize volunteers.** This would address the "resource gap" to some degree. Volunteers could do much of the work, and many citizens would be willing to help preserve the environment of something that is important to them.
7. **Get To It!** The sooner a plan is established the better chance we have of preserving the harbour. Timing should be a big priority.

A final recommendation particular to the workshop itself was made. We suggested that it be moved to City Hall or some other venue that would make the workshop both accessible to more people, and more visible to the community. If more people knew that such a workshop was being held, they might be interested in the recommendations and seek to learn more.

Appendix C

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